Modeling the Volatility of Rubber Futures by Exchange Rate and Climate Change

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Abstract

Natural rubber is a plant of economic importance of Thailand, which has been the world's biggest producer and exporter since 1991. In 2014, Thailand covers the cultivation area of natural rubber of 3.6 million hectares, of which tapping area is 2.78 million hectares. In this paper, we applied the Gaussian copula, T copula, Clayton copula, Frank copula, Gumbel copula, Joe copula, BB1 copula, BB6 copula, BB7 copula, BB8 copula and rotate copulas to determine the relationship between the volatility of Thai rubber futures return, exchange rate of Thai baht and climatic factors. Based on these results, climatic factors and fluctuations in the exchange rate market have significant effects on Thai rubber futures returns. With regards the analysis methods, no single method can provide a complete picture of the dependencies and interrelatedness of the various asset markets. We hope that the results of this study can be used by investor of Thai rubber futures, as well as other key stakeholders in the rubber futures.

Keywords: Volatility, Copula, Rubber Futures, Exchange Rate, Climatic Factors

1. Introduction

The rubber material includes nature rubber and synthetic rubber. The nature rubber is about 40% of total would rubber consumption, and more than 70% is used for the tires industry. The others are used for the fabrication of various materials in the paramedical sector. Thailand, Malaysia and Indonesia are the considered major producers and exporters of rubber.

Natural rubber is a plant of economic importance of Thailand, which has been the world's biggest producer and exporter since 1991. In 2014, Thailand covers the cultivation area of natural rubber of 3.6 million hectares, of which tapping area is 2.78 million hectares. Thai rubber production reached 4.2 million tons in 2014, being domestically consumed for 541,000 tons and exported in primary-processing form of 3.78 million tons, data from the Office of Agricultural Economics. Natural rubber generated export revenue of over 600,000 million Baht per annum. The cultivation area is mainly in the South, in which the province of Suratthani has the largest cultivation area, followed by Songkhla, Nokornsithammarat, Trang and Yala respectively. In addition to having the large area of rubber plantation, Suratthani is also home to many rubber processing factories. It plays a significant role in generating income and contributes to the economic growth of the country.

The exchange rate becomes a crucial factor of international trading because trading in Thailand is highly dependent on the USA and Japan. Furthermore, other uncontrollable elements, such as tsunamis, floods, political environments, and so on, directly affect the exchange rate.

In the 90's, because the North East of Thailand as a marginal area with poor soils and limited water availability, Thailand government decide to expend to be rubber planting area for fixing the populations problem. So far, almost 10% of the Thai population lives, in a way or another, from the production, trading or transformation of natural rubber. Therefore, crude rubber output has increased due to the assistance program launched by the Thai government, which aimed to provide better options and varieties to farmers. This makes natural rubber a very important cash crop in Thailand, for its economical and social impact.

Rubber trees thrive in tropical climates with high temperature (e.g., 26 ℃ to 32 ℃) and rainfall with average precipitation of 2000 mm or more. In the Southeast Asian region, rubber output varies according to the season: (a) output reduction is highest during the high dry period from February to April; (b) highest output is achievable during the monsoon period from May to July, (c) output is reduced to some extent during the mild dry period from August to October, and (d) an increase in output occurs during the high monsoon period from November to January.

Heavy rainfall normally causes an annual increase in rubber output during the third and the fourth quarters, particularly in the southern regions that comprise the largest area of domestic rubber production. In these two periods, rubber prices tend to decline due to the increase in supply. Because the output is not easy to be increased in the shot period, the price of rubber will be effected by climate change significantly. The top 25 rubber producing areas in Thailand are Burirum, Chanthaburi, Chon buri, Chumphon, Krabi, Nakhon Thammarat, Narathiwat, Nong Khai, Pattani, Phangnga, Phattaluang, Phetchabun, Phitsanulok, Ranong, Rayong, Sakon Nakhon, Satun, Si Sa Ket, Songkhla, Surat Thani, Trad, Trang, Udon Ratchathuni, Udon Thani and Yalain.

After Mills (1927) present the common economic variable are not normal, the excess kurtosis (or fat tails) and skewness in univariate distributions has often be widely discussed. On the other hand, Wei Chen Sang et al. (2012) prove that the volatility of Thai rubber spot price return is linked with volatility in the exchange rate and crude oil markets as well as climatic factors by using *VARMA-GARCH, VARMA-AGARCH and Copula-based GARCH models*. Therefore, we want to discuss about the relationship between rubber futures price, climatic factors and exchange rate.

2. Review of the literature

Measuring volatility is most common in the financial market, where researchers examine interrelationships among different stock markets, because movements in prices in these markets are not immune from each other due to the globalized nature of trading. For example, Eun and Shim (1989) report that the stock market in the USA is the main source of international transmission of volatility that can, in turn, affect foreign stock markets. However, foreign stock market variations cannot explain variations within the US stock market, implying a unidirectional effect. Theodossiou and Lee (1993) prove that the US stock market has positive transmission effects on stock markets in the UK, Germany, Canada, and Japan. Kearney (2000) also notes that the variation in most stock markets in the world is derived from stock market variations in the USA and Japan, which are then transferred to Europe

With respect to volatility in the exchange rate market, Hooper and Kohangen (1978) note that changes in the margin of the exchange rate changes give way to changes in the relative price of the international product. DeGrauwe (1988), meanwhile, notes that the exchange rate risk produces substitution and income effects on the product markets, that is, exports tend to increase if the margin of exchange rate change is volatile. Doroodian (1999) concludes that fluctuation in exchange rates exert overall negative effects in international trade for developing countries.

Few studies also illustrate the importance of adaptation to climatic factors (e.g., Kaiser et al., 1993; Mendelsohn et al., 1994) to explain volatility in product markets. For example, Kaiser et al. (1993) simulate the effect of climatic factors on product market. However, their model is based on selecting an individual representative farm and simulating its returns without considering aggregation or the market-level impact of adaptation to climate change. Mendelsohn et al. (1994) examine changes in land values as well as farmers' revenues using county-level data that incorporate adaptations to climate, as reflected in current production practices. Although their study demonstrates the nature of adaptations to climatic variables, the results do not address potential changes in prices.

Finally, various studies apply copula methods to analyze correlations across markets and financial assets. Roncalli (2001) proposes a portfolio, which includes five financial assets in the London Metal Exchange. He used Gaussian copula and Student's copula to analyze the

correlation between financial assets demonstrating significant difference in correlation coefficients. Hu (2002) uses the copula model to analyze the correlation between stock market and bond market, noting that the correlation is better in a bear market than in a bull market. Bartram et al. (2004) applies the Gaussian copula function to the GJR-GARCH-t model to estimate the correction effect of lead in Euro currency among the stock markets of 17 European countries. They proved that the correlation increased only in large-scale capital markets, namely, those of France, Germany, Italy, the Netherlands and Spain, after a change in common customs tariff. Patton (2006), meanwhile, uses the copula function to build a bivariate copula model between the exchange rate of German mark and Japanese yen, then compared it with the Baba-Engle-Kraft-Kroner (BEKK) model. The result shows that the copula model can better explain the correlation between financial markets than the BEKK. They concluded that when the exchange rate of German mark and Japanese yen depreciates, the correlation becomes higher than when exchange rates appreciate.

Meng et al. (2004) examine the relationships of the futures markets, such as the soybean futures market in Dalian, USA and Japan, using the dollar/yen exchange rate as an example. Their results suggest that there is a strong dependence between different futures markets.

The aforementioned studies make it clear that the volatility of a specific asset in a market, in relation to other markets, must be examined because there is always evidence of dependencies in the movement of different markets affecting each other either positively or negatively. Hence, our modeling framework for the current study attempts to incorporate the interdependencies of Thai rubber price returns with other important markets (i.e., US dollar exchange rate and crude oil market) as well as climatic factors (i.e., precipitation and temperature).

3. Data, variables and selection criteria

Natural rubber is classified into five levels. The highest level is RSS1, but the main kind is RSS3 in spot and future markets around the world. Given that Thailand trade depends highly on the USA and Japan, the exchange rate of Thai baht is a crucial factor. Therefore, the exchange rate of Thai baht was chosen as one variable. Secondly, the growth in rubber output is closely related to seasonality. Due to the fact that temperature and precipitation are important factors in natural rubber output (as mentioned in the introduction), the variables representing the production environment of rubber were included. Thus, climatic data from 25 locations with high rubber outputs were chosen. For each variable, the observations are required from May 28, 2004 (the first trading day of AFET) to December 31, 2014. The variable names are introduced in Table 1.

Table 1. Variables used in the study

Variables	Names
x_1	Rubber Futures in Agricultural Futures Exchange of Thailand (AFET)
x_2	Exchange rate of Thai Baht
x_3	Difference between todays temperature from yesterday, 1581 observations, which is made up of average temperatures by top 25 rubber producing areas in Thailand. These are: Burirum, Chanthaburi, Chon buri, Chumphon, Krabi, Nakhon Thammarat, Narathiwat, Nong Khai, Pattani, Phangnga, Phattaluang, Phetchabun, Phitsanulok, Ranong, Rayong, Sakon Nakhon, Satun, Si Sa Ket, Songkhla, Surat Thani, Trad, Trang, Udon Ratchathuni, Udon Thani and Yalain.
x_4	Average precipitation per day, 1581 observations, where the average precipitation is from the top 25 rubber producing areas named above.

3.1 Vine copula of four variables

The vine structure of four dimensional canonical is generally expressed in the following:

$$f(x_1, x_2, x_3, x_4) = f(x_1) \cdot f(x_2) \cdot f(x_3) \cdot f(x_4)$$
$$\cdot c_{12}\big(f(x_1) \cdot f(x_2)\big) \cdot c_{13}\big(f(x_1) \cdot f(x_3)\big) \cdot c_{14}\big(f(x_1) \cdot f(x_4)\big)$$
$$\cdot c_{23|1}\big(f(x_2|x_1) \cdot f(x_3|x_1)\big) \cdot c_{24|1}\big(f(x_2|x_1) \cdot f(x_4|x_1)\big)$$
$$\cdot c_{34|12}\big(f(x_3|x_1, x_2) \cdot f(x_4|x_1, x_2)\big) \tag{1}$$

According to AIC, we want to find out the best copulas in C-Vine copula which are T copula, Gaussian copula, Archimedean copula families such as .Clayton, Gumbel, Frank and Joe.

(1) Bivariate Gaussian Copula

$$C(u_1, u_2) = \phi_\rho(\phi^{-1}(u_1), \phi^{-1}(u_2))$$

(2)

(2) Bivariate Student-t Copula

$$C(u_1, u_2) = t_{\rho,v}(t_v^{-1}(u_1), t_v^{-1}(u_2)), \tag{3}$$

(3) Bivariate Archimedean Copula

$$C(u_1, u_2) = \varphi^{[-1]}(\varphi(u_1) + \varphi(u_2)) \tag{4}$$

Where $\varphi: [0,1] \rightarrow [0, \infty]$ is a continuous strictly decreasing convex function such that $\varphi(1) = 0$ and $\varphi^{[-1]}$ is the pseudo-inverse. φ is called the generator function of the copula C(Nelsen 2006).

Furthermore, the packages provides functionality for four Archimedean copula families

with two parameters, namely the Clayton-Gumbel, the Joe- Gumbel, the Joe-Clayton and the Joe-Frank. Following Joe (1997) we simply refer to them as BB1, BB6, BB7 and BB8, respectively.

For each family, we assigned a number which is called by the argument family in many functions. Corresponding parameters are called by the arguments par and par2, where par2 is needed for the degrees of freedom parameter of the Student-t copula as well as for the parameter of the BB1, BB6, BB7 and BB8 copulas. In addition to these families, we implemented rotated versions of the Clayton, Gumbel, Joe and the BB families. When rotating them by 180 degrees, one obtains the corresponding survival copulas, while rotation by 90 and 270 degrees allows for the modeling of negative dependence which is not possible with the standard non-rotated versions. In particular, the distribution functions C90, C180 and C270 of a copula C rotated by 90, 180 and 270 degrees, respectively, are given in following:

$$C_{90}(u_1, u_2) = u_2 - C(1 - u_1, u_2)$$
(5)
$$C_{180}(u_1, u_2) = u_1 + u_2 - 1 + C(1 - u_1, 1 - u_2)$$
(6)
$$C_{270}(u_1, u_2) = u_1 - C(u_1, 1 - u_2)$$
(7)

3.2 Symmetrized Joe-Clayton(SJC) Copula

For catch the tail dependence, we use SJC copula which is clearly only a slight modification of the original Joe-Clayton copula, but by construction it is symmetric when $\tau^U = \tau^L$. From an empirical perspective the fact that the SJC copula nests symmetry as a special case makes it a more interesting specification than the Joe-Clayton copula.

$$C_{sjc}(u, v|\tau^U, \tau^L) = 0.5 \cdot (C_{JC}(u, v|\tau^U, \tau^L) + C_{JC}(1 - u, 1 - v|\tau^U, \tau^L) + u + v - 1)$$
(8)

4. Empirical Results

In this paper, we use Gaussian copula, T copula, Clayton copula, Frank copula, Gumbel copula, Joe copula, BB1 copula, BB6 copula, BB7 copula, BB8 copula and rotate copulas to analyze co-movement from function 1.

The analysis of the volatility between rubber futures return and three variables which are exchange rate of Thai baht, average precipitation and average temperature using copula families model. From table 2, we can know that all correction coefficients are positive and the coefficient of $c_{34|12}$ is more significant than others which the best copula method is Rotated BB8 copula (90 degrees). On the other hand, the Frank Copula is the best copula method of c_{14} and $c_{24|1}$.

Table 2: Estimation result

	coefficient	Std. Error	τ	best copula method
c_{12}	0.02352892	8.5250031	-0.014980360	Student-T copula
	(0.02806404)	(2.1521255)		
c_{13}	0.07066851	0.0000000	0.034128355	Gaussian copula
	(0.03026469)	(0.0000000)		
c_{14}	0.06770827	0.0000000	0.007522796 -	Frank copula
	(0.15439214)	(0.0000000)		
$c_{23|1}$	0.07313948	0.0000000	0.035279573	Rotated Clayton copula
	(0.02927219)	(0.0000000)		(180 degrees)
$c_{24|1}$	0.23056289	0.0000000	0.025604493	Frank copula
	(0.15447233)	(0.0000000)		
$c_{34|12}$	1.25414863	-0.8652115	0.068336016	Rotated BB8 copula
	(0.20556654)	(0.1802589)		(90 degrees)

We present the estimation results for SJC model. If the conditional copula of (X_t, Y_t) is SJC, the unconditional copula will not in general be SJC. The estimation results are present in Table 3. The upper tail parameters in the SJC copula were found to significantly change, and a test of the significance of a break for this copula yielded the t-stats of more than 2.54. We also present the plot of the conditional upper tail dependence by the time-varying SJC copula model in Figures 1.

Table 3: Time-varying rotated SJC copula (90 degrees)

	Parameter	St. Error	t-stats
$Constant^L$	1.0972	0.845	1.2991
α^L	-8.3006	6.083	-1.3646
β^L	0.6478	0.208	3.1217
$Constant^U$	-1.9123	0.013	-150.8553
α^U	-0.8805	0.064	-13.7062
β^U	2.9773	0.008	-13.7062

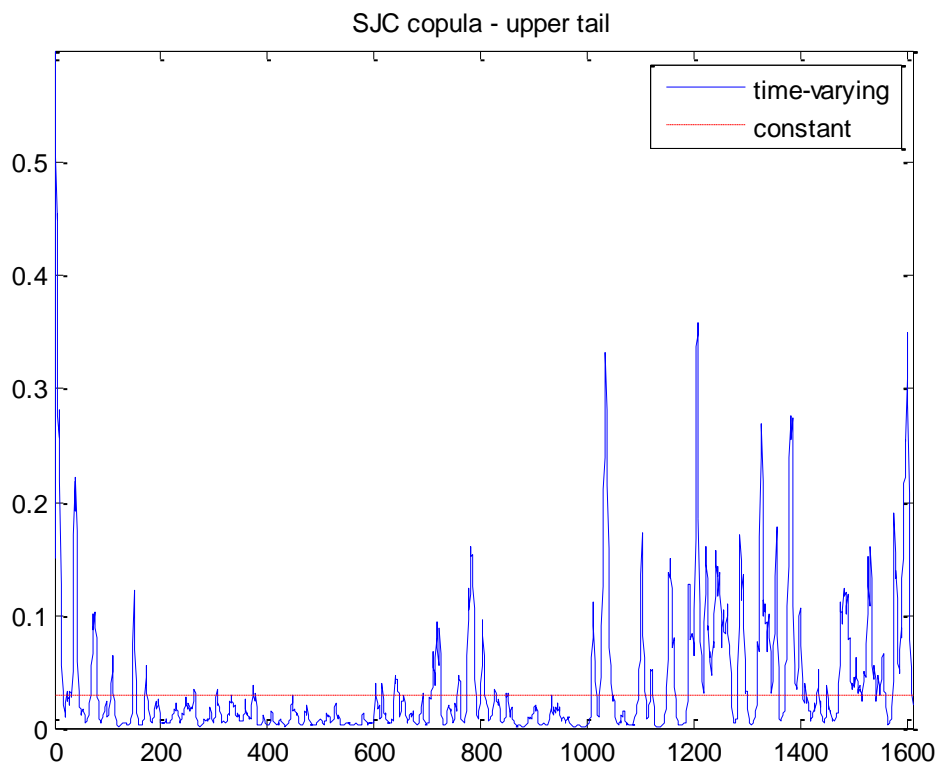|	
Copula likelihood	10.853

Figure 1

5. Concluding Remarks

Based on these results, climatic factors and fluctuations in the exchange rate market have significant effects on Thai rubber futures returns. Therefore, the investor should consider the volatilities Thai baht Exchange market as well as climatic conditions when forecasting the Thai rubber future returns.

With regards the analysis methods, no single method can provide a complete picture of the dependencies and interrelatedness of the various asset markets. Therefore, we try to find out the best copula method to be used to obtain a complete picture of the complexities associated with analyses of price volatility. We hope that the results of this study can be used by investor of Thai rubber futures, as well as other key stakeholders in the rubber futures.

The agriculture is the basic industry in Thailand. Since the farmers are the mainstay of the Thailand's economy and the number of people was large, so Thailand government should take care of them. Because of the farmers income was lower, they may not have enough

money to hedge in commodities futures market. In this study, there are two suggestions for Thailand government. For the different multivariate Copula model, we can know that the exchange rate and climatic factors which we discuss in this paper can affect the rubber futures return in AFET. Therefore, I suggest Thailand government found the hedge mutual funds which were investing in every commodities futures exchange in the world. It can concentrate the funds from farmer to invest in each commodities futures market. They can invest or hedge in the futures market if they have enough funds to invest.

References

Bartram, S., S. J. Taylor and Y-H Wang, (2004), "The Euro and European Financials market dependence", Working Paper, Lancaster University and National Central University.

Eun, C. S. and S. Shim, (1989), "International Transmission of Stock Market Movements." *Journal of Financial and Quantitative Analysis*, 24, 241-257.

Hu, L. (2002), "Dependence Patterns acoss Financial Market: Methods and Evidence", working paper, Yale University.

Kaiser, H. and Drennen, T. (eds.), (1993), "Agricultural Dimensions Global Climate Change." Delray Beach, FL: St. Lucie Press.

Kearney, C., (2000), "The determination and international transmission of stock market volatility." *Global Finance Journal*, 11(1-2), 31-66.

Mendelsohn, R., Nordhaus, W. and Shaw, D. (1994), "The Impact of Global Warming on Agriculture: A Ricardian Analysis." *American Economic Review* 84:753-71.

Meng, J. L., JiWen Si and Pu Gong (2004), "A Dependence Study for Futures Markets with Copula", Asian FA/TFA/FMA conference 2003-2004 in Taipei-2004/7/14.

Patton, A. J., (2006), "Modelling asymmetric exchange rate dependence", *International Economics Review* 47(2), pp. 527-556.

Roncalli, T., Bouy'e, E., Durrleman, V., Nikeghbali, A., and Riboulet, G. (2001), "Copulas: an open filed for risk management", Credit Lyonnais.

Sang, Wei Chen, Songsak Sriboonchitta, Wan Tran Huang, Sanzidur Rahman and Aree Wiboonpongse, (2012), "Modeling volatility and interdependencies of Thai rubber spot price return with climatic factors, exchange rate and crude oil markets", *Journal of Financial Review*, volume 16, p1-20.

Theodossiou, P. and U. Lee, (1993), "Mean and Volatility Spillovers across Major National Stock Market: Further Empirical Evidence." *Journal of Finance Research*, 16, 337-350.