CHAPTER 3

Dependence Structure between Crude Oil, Soybeans, and Palm Oil in ASEAN Region: Energy and Food Security Context

This chapter presents the empirical results for the study of "Dependence structure between crude oil, soybeans, and palm oil in ASEAN region: energy and food security context", which is extended from the original papers that had been published in "Modeling Dependence in Econometrics", Advances in Intelligent Systems and Computing Volume 251, pp 329 – 341. The original paper can be found in Appendix B.

3.1 Introduction

By 2015, the nations in the Southeast Asian region consisting of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam will agree on establishing an ASEAN Economic Community (AEC), which has a total population of approximately 600 million people. This regional integration shall lead to a single market and production that will induce free movement of goods, services, investment, capital, and skilled labor across the ASEAN region (ASEAN Secretariat, 2011a, 2012). The ASEAN boundary is adjacent to the south of China and is linked to the east of India, both by sea and land. India and China are part of the BRIC countries, which are the newly industrialized countries, and are considered as two of the nations that have fast growing economies (Wikipedia, 2013). According to the information mentioned above, the premise is that the economic geography makes the AEC play an important role in the global economy. However, during the past several years, the AEC has remained restricted due to some challenging circumstances caused by the global financial crisis in 2008. In addition, the food and fuel crises have caused a huge burden on the people who are poor and near-poor in the ASEAN region, and created a negative impact with regard to their social and economic development (ASEAN Secretariat, 2010). The rise in food prices came about due to many factors, such as climate change which caused a decline in the agricultural production, a rise in fuel prices which led to a domino effect on the cost of production, and the increase in consumer demand (Asian Development Bank, 2011).With regard to the rise in fuel prices, the incidence of such factors was due to an increasing demand in Asia, especially in the emerging markets of India and China (Len, 2007). The rise in food and energy prices is a real challenge for the ASEAN members while trying to find any crucial means to cooperate in the short- and long-term situations to solve the problems because food[1] and energy[2] security are fundamental for upholding the ASEAN economic and social development goals (ASEAN Secretariat, 2011b).

Palm oil and soybeans are food commodities that are related to food security in the ASEAN region because they are used as raw materials in food production and are converted to the necessary goods, and also used for other aspects of daily life. Palm oil and soybeans can be modified as cooking oil**,** shortening**,** margarines, soy milk, soy sauce, tempeh, tofu, etc. Moreover, palm oil and soybean oil can be used to produce alternative energy such as the biodiesel types, Palm Methyl Ester (PME) and Soy Methyl Ester (SME), respectively. In ASEAN, palm oil can be produced sufficiently for intra-regional demand and the remaining parts can be kept aside for exportation. In 2012/2013, Indonesia and Malaysia exported palm oil of an approximate volume of 37,300 thousand metric tons, or 89.66% of the total world exports, which was 41,603

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[1] FAO (2009: p. 1) definition: Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life. The four pillars of food security are availability, access, utilization, and stability. The nutritional dimension is integral to the concept of food security.

[2] United Nations (2004: p. 42) definition: Energy security is a term that applies to the availability of energy at all times in various forms, in sufficient quantities, and at affordable prices, without unacceptable or irreversible impact on the environment. These conditions must prevail over the long term if energy is to contribute to sustainable development. Energy security has both a producer and a consumer side to it.

thousand metric tons (USDA, 2013a). However, in the case of soybeans, it has to be imported from outside the region. In 2012/2013, Indonesia, Thailand, and Vietnam imported about 5,300 thousand metric tons or 5.66% of the total world imports, which was 93,587 thousand metric tons (USDA, 2013b).

ASEAN has crude oil resources and oil production, but does not have a sufficient supply to meet the intra-regional demand. In 2011, ASEAN imported crude oil worth not less than 90,000 million US dollars (ASEAN Secretariat, 2013). ASEAN imports crude oil especially from the Middle East (Speed, 2012). Although the crude oil benchmark prices of the international crude oil markets are from Brent, West Texas Intermediate (WTI), Dubai, and Maya, each of these markets is related to one another. It was found that in times of crude oil market stress, the crude oil price in each market tends to have co-movement with the same intensity (Reboredo, 2011). In addition, we found that the crude oil markets are related to the food markets. As in the previous studies of the relationship between energy and agricultural prices, it can be concluded that the long-run agricultural prices can be driven by the energy prices and that volatility in the energy markets is transmitted to the food markets (Serra and Zilberman, 2013).

Over the past several years, there have been some evidences of significant volatility transmissions between the crude oil prices in each of these markets. Moreover, the volatility in the oil prices can be transmitted to the various food markets. Thus, it is interesting to analyze the relationship between the crude oil benchmark prices of the ASEAN and the prices of the two food commodities that can be used to generate alternative energy, which are the following: (1) palm oil, which can be produced and be sufficient for intra-regional demand and (2) soybeans, which rely on imports from outside the region. Since these commodities are related to the energy and food security for the people in the ASEAN region, and can also be substituted for each other, it would be quite interesting to learn about the dependence structure of these commodity prices. Furthermore, it will be useful for making decisions and plans for the economic and social development of the AEC. Therefore, the purposes of the study are as follows: (1) to analyze the dependence between crude oil prices (DME) and two food prices, namely, the prices of soybeans (CBOT) and palm oil (MDEX) and (2) to analyze the dependence between the soybeans and palm oil prices, with the crude oil prices as the conditioning variable.

3.2 Literature Review

Over the past several years, there have been arguments about the relationship between the energy prices (e.g., crude oil, biodiesel, and ethanol) and the agricultural commodity prices (e.g., palm oil, soybeans, corn) as to whether they are related or not. The argument was always divided between a relation and an absence of relation. From the literature review, we come to know that relationships do exist between the energy prices and the agricultural commodity prices; what is more, there are relationships between the prices of the different agricultural commodities themselves. The findings on these relationships depend on many factors such as the period of study, the data frequency, the statistical analysis, and the modeling. As for modeling, a number of different models were used in the studies prior to this study. Baffes (2007) used the ordinary least squares (OLS) to analyze the relationship between the commodity prices and the crude oil price. Serra and Zilberman (2013) mentioned about many econometrics and statistical models that the previous studies used to find the relationship between the energy prices and the agricultural commodity prices, and the relationships between the prices of the different commodities. A few of such applicable tools are cointegration, causality, vector error correction model (VECM), vector autoregressive (VAR), autoregressive distributed lag models (ARDL), vector auto regression moving-average (VARMA), stochastic volatility model with Merton jumps (SVMJ), panel data, minimal spanning and hierarchical trees, random parameter model, wavelet, GARCH modeling, and copula modeling. As mentioned above, we found that the statistics used for analyzing are both parametric and nonparametric, and that the relationship analysis between the variables is both linear and non-linear.

There were several models and each of the models was based on different assumptions in order to test the data. Sriboonchitta et al. (2013) applied the copula based GARCH for modeling the volatility and dependency of the agricultural price and production indices of Thailand. Based on the study, the work mentioned that this approach provided more flexibility for finding out the joint distributions and the transformation of the invariant correlation, without the assumption of linear correlation. Therefore, in this study, we used the GARCH(1,1) model (Bollerslev, 1986) to examine the volatility of the commodity daily prices which are generally non-normal distributions and applied the vine copula model to examine the relationship between each commodity.

3.3 Methodology

The R-package fGarch by Wuertz and Chalabi (2013) was used to estimate the GARCH(1,1) model with the skewed student-T (SkT) residual distribution for the marginal distribution of the log-difference $\ln\frac{P_t}{P_{t-1}}$ or the growth rate of crude oil prices, palm oil prices, and soybeans prices. The standardized residuals with the skewed student-T were transformed to copula data $(F_1(x_1), F_2(x_2), F_3(x_3))$ by using the empirical distribution function. After that, we used the R-package CDVine which was developed by Brechmann and Schepsmeier (2013) to estimate the bivariate copula and C-vine copula. For the time-varying copula, we followed method endorsed by Patton (2006a).

This study used the C-vine copula modeling to analyze the dependence between the crude oil prices from the Dubai market (DME) and the two food prices consisting of palm oil prices from the Malaysia market (MDEX) and soybeans prices from the Chicago market (CBOT), which no one has studied before. The structure of the C-vine model is shown in Figure 3.1 This study selected crude oil which was the first root node, as Brechmann and Schepsmeier (2013) hold the view that a vine structure can be chosen manually or through expert knowledge. Aas et al. (2009) said that modeling C-vine might be advantageous when we know a main variable that governs the interactions in the data, or when it plays an important role in the dependence structure and when the others are linked to it. Therefore, our assumption in this study is that crude oil prices is a key variable as Serra and Zilberman (2013) point out that energy prices can drive the long-run agricultural price levels.

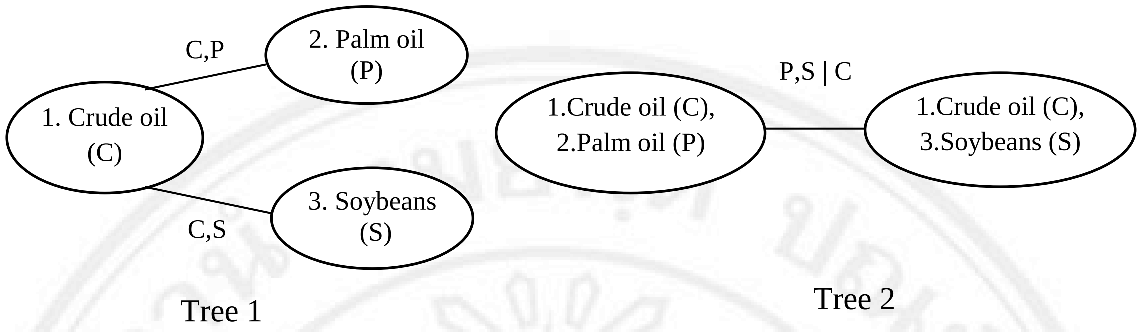

Figure 3.1 The pair-copulas of three-dimensional C-vine trees

3.4 Data and Empirical Results

To analyze the relationship between crude oil prices and two food prices (palm oil and soybeans), we selected the commodity prices that are related to the AEC. The crude oil benchmark price for the Asian market is the Dubai (Oman) crude oil price (Koyama, 2011) since the Middle East is the major source of crude oil for ASEAN (Speed, 2012). Thus, the crude oil price of the Dubai Mercantile Exchange (DME) was used in this study. Palm oil prices were obtained from the Malaysia Derivatives Exchange (MDEX) because Malaysia is a major producer and a world exporter of palm oil (USDA, 2013a). In ASEAN, soybean production in the intra-region was insufficient for meeting the demand; most of the soybeans was imported from Brazil, Argentina, and America. Indonesia, Thailand, and Vietnam are the major importers of soybeans in the Asian region due to their demand for soybeans in the food industry, livestock industry, and so on (USDA, 2013b, 2013c, 2013d, 2013e). Therefore, we used the soybeans prices of the Chicago Board of Trade (CBOT) since it provides an updated data and it can be used as a reference price in the world market. The observations were based on the Futures 1-Pos of the daily close prices during the period from 1 June 2007 to 15 March 2013, from the EcoWin database. Each price data series was transformed into the log-difference, $\ln \frac{P_t}{P_{t-1}}$, or the growth rates of the prices before were used to analyze by using the vine copula based GARCH model.

Table 3.1 presents a descriptive statistics of the growth rates of crude oil, palm oil, and soybeans. Crude oil and soybeans have positive average growth rates but palm oil has negative average growth rates. All of three data series exhibit negative skewness. If skewness is negative, the market has a downside risk or there is a substantial probability of a big negative return. The kurtosis of these data is greater than 3. Therefore, this kurtosis is called super Gaussian and leptokurtic. This means that the growth rates of the empirical data have a typically spiky probability distribution function with heavy tails. The null hypothesis of the normality of the Jarque-Bera tests are rejected in all the data series. The Dickey-Fuller test shows that these data series are stationary at p-value 0.01.

Table 3.1 Data Descriptive Statistics for Log-difference of Crude Oil, Palm Oil, and Soybeans Prices

	Crude oil	Palm oil	Soybeans
Mean	0.000354	-0.000107	0.000403
Median	0.000899	0.000000	0.001304
Maximum	0.133869	0.097638	0.203209
Minimum	-0.133661	-0.110391	-0.234109
Std. Dev.	0.023000	0.020276	0.020557
Skewness	-0.157438	-0.347154	-0.898968
Kurtosis	7.68	7.03	23.50
Jarque-Bera	1,265.75	961.06	24,341.97
(p-value)	*(0.0000)*	*(0.0000)*	*(0.0000)*
p-value of Dickey-Fuller test	*0.01*	*0.01*	*0.01*
Number of observations	1,379	1,379	1,379

From the data given in Table 3.1, it can be seen that the three data series are inappropriate with normal distribution, and exhibit negative skewness and excess kurtosis. Therefore, the GARCH(1,1) with the skewed student-T residual distribution, $\varepsilon_t \sim SkT(\nu, \gamma)$, was modeled for examining the volatility and for estimating the marginal distributions.

Figure 3.2 presents the log-prices and the growth rates of crude oil, palm oil, and soybeans prices, along this period. It can be seen that each of the “log-prices” has a corresponding movement and that the growth rates of the prices have more fluctuation.

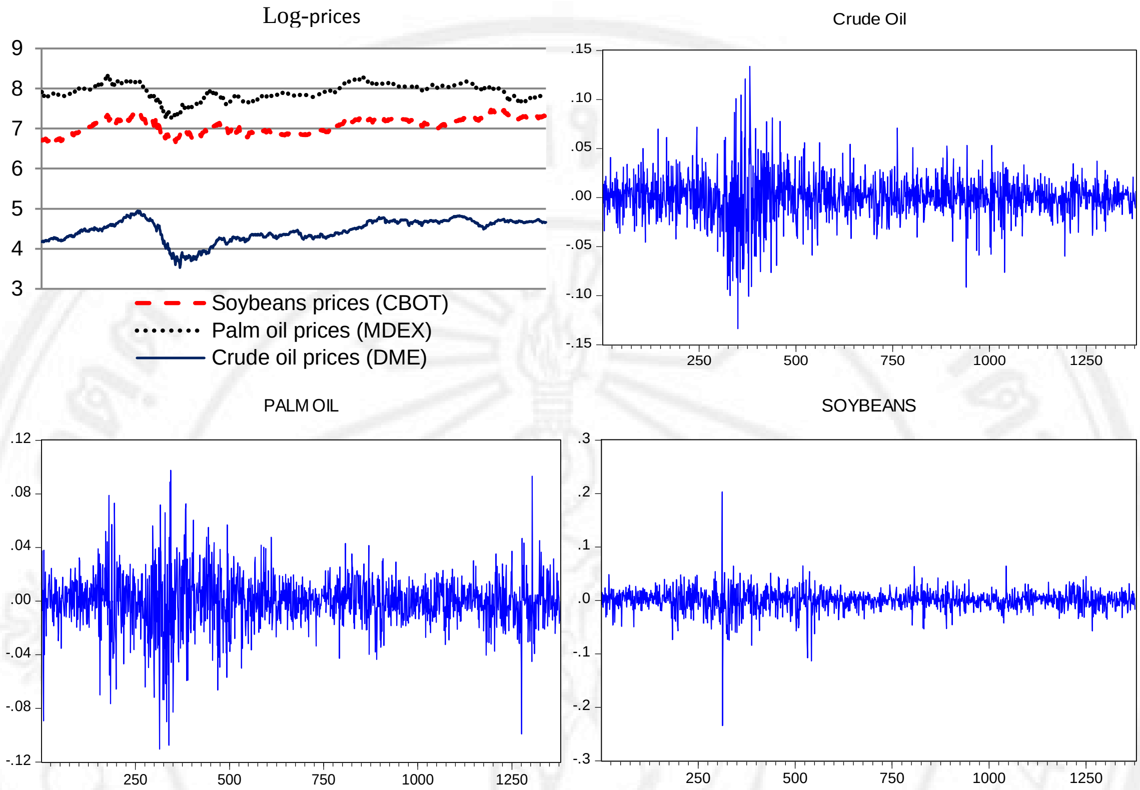

Figure 3.2 The log-prices, and the growth rates of crude oil, palm oil, and soybeans prices

Table 3.2 presents the result of GARCH(1,1) with skewed student-T residual. The asymmetry parameters, γ, are significant and less than 1, exhibiting that all the data series are skewed to the left. For crude oil, palm oil, and soybeans, the $\alpha + \beta$ are 0.9980, 0.9901, and 0.9894, respectively; this implies that their volatilities have long-run persistence. For the short-run effect of the unexpected factors, we consider the event from the α parameter. Therefore, we can see that they have close values (0.0529, 0.0746 and 0.0483) and a small impaction for volatility.

Table 3.2 Results of GARCH(1,1) with Skewed Student-T Residual for Log-difference of Crude Oil, Palm Oil, and Soybeans Prices

	Crude oil	Std. error *(p-value)*	Palm oil	Std. error *(p-value)*	Soybeans	Std. error *(p-value)*
ω	2.325e-06	1.749e-06 (0.184)	3.903e-06	1.721e-06 (0.0233 *)	4.428e-06	1.674e-06 (0.00817 **)
α	0.0529	1.214e-02 (1.32e-05 ***)	0.0746	1.501e-02 (6.75e-07 ***)	0.0483	1.115e-02 (1.52e-05 ***)
β	0.9451	1.231e-02 (< 2e-16 ***)	0.9155	1.606e-02 (< 2e-16 ***)	0.9411	1.173e-02 (< 2e-16 ***)
ν (degree of freedom)	5.067	7.455e-01 (1.07e-11 ***)	7.681	1.485e+00 (2.31e-07 ***)	4.917	6.933e-01 (1.32e-12 ***)
γ (skewness)	9.418e-01	3.112e-02 (< 2e-16 ***)	9.685e-01	3.557e-02 (< 2e-16 ***)	8.795e-01	2.889e-02 (< 2e-16 ***)
Log likelihood	3,499.523	-	3,654.827	-	3,659.68	-
K- S test *(p-value)*	-	- (1)	-	- (0.9208)	-	- (1)
Box-Ljung test *(p-value)*	-	-	-	-	-	-
1st moment	-	- (0.5832)	-	- (0.2515)	-	- (0.9540)
2nd moment	-	- (0.7921)	-	- (0.8898)	-	- (0.4999)
3rd moment	-	- (0.7765)	-	- (0.0732)	-	- (0.4433)
4th moment	-	- (0.6423)	-	- (0.8803)	-	- (0.6692)

The results of the K-S test show that these marginal distributions are uniform, by accepting the null hypothesis at p-values equal to 1 or nearly 1. The results of the Box-Ljung test provide that all of the four moments of all the marginal distributions are i.i.d. by accepting the null hypothesis that does not have a serial correlation at p-value greater than 0.05. Therefore, our marginal distributions were not misspecified and can be used for the copula model.

3.4.1 Results of C-vine Copula Analysis

Figure 3.1 presents each of the pair-copulas of the three-dimensional C-vine tree; there are two pair-copulas in Tree 1 and one pair-copula in Tree 2. The first and second pair-copulas in Tree 1 are Crude oil–Palm oil (C,P) and Crude oil–Soybeans (C,S), respectively. The third pair-copula in Tree 2 is a conditional pair-copula, Palm oil–Soybeans given Crude oil (P,S | C).

We use the Gaussian copula, Student's T copula, Clayton copula, Gumbel copula, Frank copula, Joe copula, rotated Clayton 180°copula, rotated Gumbel 180° copula, and rotated Joe 180° copula to fit the data. The AIC and the BIC are used to appraise as to which copula is the best fit. Kendall's tau correlation which was transformed from the copula parameter was used because each family of copula has a different range of copula parameters; hence we inverse a copula parameter into a Kendall's tau correlation, and it is bound on the interval [-1,1]. Kendall's tau is a measure of concordance which is a function of copula; thus, we can use it to assess the range of dependence covered by the families of copula. A goodness-of-fit test based on Kendall's tau provides the Cramér-von Mises (CvM) and Kolmogorov-Smirnov (KS) test statistics and the estimated p-values by bootstrapping (Brechmann and Schepsmeier, 2013) to test the appropriateness of the copula model under the null hypothesis that the empirical copula C belongs to a parametric class $\mathcal{C}$ of any of the copulas, $H_0: C \in \mathcal{C}$.

The results of the pair-copulas Crude oil–Palm oil (C,P), Crude oil–Soybeans (C,S), and Palm oil–Soybeans given Crude oil (P,S | C) are presented in Table 3.3, Table 3.4, and Table 3.5, respectively.

Table 3.3 presents the results of Crude oil–Palm oil (C,P). Considering the values of the AIC and the BIC, the three most appropriate copulas in order are the Gaussian, Student's T, and rotated Gumbel 180°. But the second parameter (ν) of the Student's T copula is insignificant with p-values greater than 0.05. The CvM and KS tests of the Gaussian, Student's T, and rotated Gumbel 180° copula accept the null hypothesis with p-values greater than 0.05, which means that the dependence structure of the data series is appropriate for a chosen family. Therefore, the Gaussian copula is chosen to explain the dependence structure of this pair-copula with a copula parameter 0.2495 and a Kendall's tau correlation 0.16.

Table 3.3 Results of Crude Oil–Palm Oil (C,P) in Tree 1 of a C-vine Copula Model

Tree	Pair-copula	Copula family	Copula parameter	Std. error *(p-value)*	Kendall's tau	AIC	BIC	*p-value*	
								CvM	KS
1	C,P	Gaussian	0.2495	0.0245 *(0.0000)*	0.1600	-86.4655	-81.2364	0.24	0.19
		Student's T	0.2494	0.0250 *(0.0000)*	0.1605	-84.8997	-74.4415	0.59	0.61
			ν =53.4942	82.9504 *(0.2596)*					
		Clayton	0.2850	0.0380 *(0.0000)*	0.1247	-70.5103	-65.2812	0.04	0.14
		Gumbel	1.1512	0.0221 *(0.0000)*	0.1313	-62.4044	-57.1753	0	0
		Frank	1.4756	0.1652 *(0.0000)*	0.1605	-77.7904	-72.5612	0.01	0
		Joe	1.1669	0.0316 *(0.0000)*	0.0872	-37.6619	-32.4328	1	1
		rotated Clayton 180°	0.2487	0.0368 *(0.0000)*	0.1106	-55.9746	-50.7455	0	0.02
		rotated Gumbel 180°	1.1675	0.0222 *(0.0000)*	0.1434	-77.9826	-72.7535	0.05	0.07
		rotated Joe 180°	1.2113	0.0325 *(0.0000)*	0.1076	-59.0245	-53.7953	0.99	0.95

Table 3.4 presents the results of Crude oil–Soybeans (C,S). Considering the values of the AIC and the BIC, the three most appropriate copulas in order are Student's T, Gaussian, and Frank. Although the Student's T copula is the best fit according to the AIC and the BIC, it does not give any results for the CvM and KS tests by estimation in the R package CDVine. The Gaussian copula is a second order of the AIC and the BIC values, and shows that the CvM and KS tests accept the null hypothesis with p-values greater than 0.05. For the Frank copula, the CvM and KS tests reject the null hypothesis with p-values less than 0.05, which means that the Frank copula is not an appropriate model. Therefore, the Gaussian copula is chosen to explain the dependence structure of this pair-copula with a copula parameter of 0.3545 and a Kendall's tau correlation of 0.23

Table 3.4 Results of Crude Oil–Soybeans (C,S) in Tree 1 of a C-vine Copula Model

Tree	Pair-copula	Copula family	Copula parameter	Std. error *(p-value)*	Kendall's tau	AIC	BIC	*p-value*	
								CvM	KS
1	C,S	Gaussian	0.3545	0.0222 *(0.0000)*	0.2307	-182.9177	-177.6885	0.07	0.08
		Student's T	0.3606	0.0236 *(0.0000)*	0.2349	-190.5264	-180.0682	NA	NA
			ν =13.6722	5.1333 *(0.0039)*					
		Clayton	0.4726	0.0419 *(0.0000)*	0.1911	-169.2281	-163.9989	0.01	0.02
		Gumbel	1.2575	0.0253 *(0.0000)*	0.2048	-146.7611	-141.5319	0	0
		Frank	2.2742	0.1692 *(0.0000)*	0.2407	-179.5645	-174.3354	0.01	0.01
		Joe	1.2926	0.0363 *(0.0000)*	0.1425	-90.5817	-85.3526	1	1
		rotated Clayton 180°	0.3868	0.0408 *(0.0000)*	0.1620	-112.0563	-106.8272	0	0
		rotated Gumbel 180°	1.2796	0.0256 *(0.0000)*	0.2185	-184.84	-179.6109	0.01	0.02
		rotated Joe 180°	1.3699	0.0378 *(0.0000)*	0.1730	-150.4683	-145.2392	1	1

The parameter of each pair-copula from an appropriate copula family in Tree 1 was used to construct the conditional pair-copula of Palm oil–Soybeans given Crude oil (P,S | C) in Tree 2 of the C-vine copula model, and the results are shown in Table 3.5

Table 3.5 presents the results of Palm oil–Soybeans given Crude oil (P,S | C). Considering the values of the AIC and the BIC, the three most appropriate copulas in order are the Gaussian, Student's T, and Frank. Although the second parameter (ν) of the Student's T copula is insignificant with p-values greater than 0.05, it does not give any results for the CvM and KS tests by estimation in the R package CDVine. The CvM and KS tests of the Gaussian and Frank copulas accept the null hypothesis with p-values greater than 0.05, which means that the dependence structure of the data series is appropriate for a chosen family. Therefore, the Gaussian copula is chosen to explain the dependence structure of this conditional pair-copula with a copula parameter 0.2303 and a Kendall's tau correlation 0.15.

Table 3.5 Results of Palm Oil–Soybeans given Crude Oil (P,S | C) in Tree 2 of a C-vine Copula Model

Tree	Pair-copula	Copula family	Copula parameter	Std. error (*p-value*)	Kendall's tau	AIC	BIC	*p-value*	
								CvM	KS
2	P,S | C	Gaussian	0.2303	0.0249 *(0.0000)*	0.1480	-73.0587	-67.8296	0.98	0.99
		Student's T	0.2318	0.0258 *(0.0000)*	0.1489	-73.7226	-63.2643	NA	NA
			ν =26.1814	17.5220 *(0.0677)*					
		Clayton	0.2354	0.0368 *(0.0000)*	0.1053	-50.7716	-45.5425	0	0
		Gumbel	1.1486	0.0219 *(0.0000)*	0.1294	-64.4802	-59.2511	0.02	0.14
		Frank	1.4004	0.1657 *(0.0000)*	0.1526	-69.5958	-64.3667	0.61	0.67
		Joe	1.1764	0.0317 *(0.0000)*	0.0917	-45.3030	-40.0739	0.99	0.99
		rotated Clayton 180°	0.2458	0.0370 *(0.0000)*	0.1094	-55.0902	-49.8611	0	0
		rotated Gumbel 180°	1.1424	0.0219 *(0.0000)*	0.1246	-58.1524	-52.9233	0	0.01
		rotated Joe 180°	1.1597	0.0316 *(0.0000)*	0.0838	-37.1742	-31.9450	0.99	0.99

In addition, the results of the bivariate copula analysis of Palm oil and Soybeans (P,S) are shown in Table 3.6 The Gaussian copula was chosen to explain the dependence structure between Palm oil and Soybeans by considering the AIC and the BIC values, and the CvM and KS tests accepted the null hypothesis with p-values greater than 0.05. The Gaussian copula gives a copula parameter of 0.2970 and a Kendall's tau correlation of 0.19.

By doing a comparison between a C-vine copula model, given in Table 3.5, and a bivariate copula model, given in Table 3.6, we found out that our results show that the copula parameters and the Kendall's tau correlations of a conditional pair-copula (P,S | C) in all the copula families are less than those that were obtained from the bivariate pair-copula (P,S); for example, the Gaussian copula of the conditional pair-copula (P,S| C) offers the copula parameter and the Kendall's tau correlation as 0.2303 and 0.15, respectively. Further testing reveals that the Gaussian copula of the bivariate copula (P,S) offers the copula parameter and the Kendall's tau correlation as 0.2970 and 0.19, respectively.

This implies that crude oil price (C) has an influence on the relationship between palm oil price (P) and soybeans price (S). The crude oil price (C) is an important variable that governs the interactions in the dependence structure between the palm oil price (P) and the soybeans price (S).

Table 3.6 Results of Palm Oil–Soybeans (P,S) of a Bivariate Copula Model

Pair-copula	Copula family	Copula parameter	Std. error (*p-value*)	Kendall's tau	AIC	BIC	*p-value*	
							CvM	KS
P,S	Gaussian	0.2970	0.0236 *(0.0000)*	0.1920	-125.1169	-119.8878	0.30	0.35
	Student's T	0.2990	0.0244 *(0.0000)*	0.1933	-125.5547	-115.0965	NA	NA
		ν =26.4778	18.4553 *(0.0758)*					
	Clayton	0.3448	0.0391 *(0.0000)*	0.1471	-99.2241	-93.9950	0	0
	Gumbel	1.2044	0.0237 *(0.0000)*	0.1697	-103.7545	-98.5254	0	0
	Frank	1.8284	0.1666 *(0.0000)*	0.1967	-118.7307	-113.5015	0.02	0.16
	Joe	1.2427	0.0343 *(0.0000)*	0.1215	-69.6826	-64.4534	1	1
	rotated Clayton 180°	0.3244	0.0392 *(0.0000)*	0.1396	-85.6962	-80.4671	0	0
	rotated Gumbel 180°	1.2057	0.0236 *(0.0000)*	0.1706	-109.1733	-103.9442	0	0
	rotated Joe 180°	1.2538	0.0345 *(0.0000)*	0.1263	-79.1375	-73.9083	1	1

3.4.2 Time-varying of C-vine Copula

The dependence structures can vary over time. Thus, we also used time-varying copula models to show the co-movement of each pair-copula during this period. We used the time-varying Gaussian copula, an ARMA (1,10) process, as given in Patton (2006a). Furthermore, we added the time-varying Student's T, Joe, and rotated Joe 180° copulas which follow the pattern of the time-varying copula models, as given in Patton (2006a), and used the ARMA (1,10) type-process again. The smallest AIC and BIC values were used to select an appropriate copula family. The parameter β represents the degree of persistence in the dependences and the parameter α measures the variation over time in the dependences. The results are shown in Table 3.7 and in Figure 3.3.

Table 3.7 Results of Time-varying of C-vine Copula

Tree	Pair-copula	Copula family	Parameters	Std. error	(*p–value*)	AIC	BIC
1	C,P	Gaussian	ω =0.5093	75.4653	0.00	-82.4662	-66.7789
			β =-0.0035	-0.1339	0.45		
			α = 0.0047	1.1037	0.14		
		Student’s T	ω = 0.5096	18.9236	0.00	-82.8998	-67.2125
			β = 0.0000	0.0000	0.50		
			α = 0.0000	0.0000	0.50		
		Joe	ω = -0.6190	-87.6989	0.00	-36.0024	-20.3151
			β = 0.8283	112.4655	0.00		
			α = 0.2127	32.7605	0.00		
		rotated Joe 180°	ω = 1.0645	34.0287	0.00	-55.1766	-39.4893
			β = -0.4393	-17.6280	0.00		
			α = -0.2608	-14.3773	0.00		
1	C,S	Gaussian	ω = -0.0421	-114.4000	0.00	-188.2714	-172.5841
			β = 2.1967	1719.1000	0.00		
			α = 0.0189	87.8000	0.00		
		Student’s T	ω = -0.0413	-83.5000	0.00	-195.4912	-179.8039
			β = 2.1957	1297.1000	0.00		
			α = 0.0164	62.2000	0.00		
		Joe	ω = 1.9666	536.0502	0.00	-91.4566	-75.7693
			β = -0.7995	-302.8944	0.00		
			α = -1.4487	-79.6046	0.00		
		rotated Joe 180°	ω =1.4831	88.5026	0.00	-149.2880	-133.6007
			β =-0.4308	-41.0587	0.00		
			α = -1.1011	-58.0537	0.00		
2	P,S | C	Gaussian	ω = 0.0191	0.0009	0.00	-72.1760	-56.4887
			β = 1.9216	0.0046	0.00		
			α = 0.0353	0.0008	0.00		
		Student’s T	ω = 0.0180	0.0008	0.00	-75.0558	-59.3685
			β = 1.9274	0.0042	0.00		
			α = 0.0338	0.0007	0.00		
		Joe	ω = 0.2654	0.0235	0.00	-43.3412	-27.6539
			β = 0.2832	0.0168	0.00		
			α = -0.6307	0.0171	0.00		
		rotated Joe 180°	ω = 1.2711	0.0050	0.00	-36.6608	-20.9735
			β = -1.1737	0.0034	0.00		
			α = 1.6691	0.0137	0.00		

Tree 1, a pair-copula of Crude oil–Palm oil (C,P) gives the values of the AIC and the BIC of the time-varying Gaussian and Student’s T; we observe that these values are almost the same, and that the β and α parameters of both the copulas are insignificant with p-values greater than 0.05. The time-varying rotated Joe 180° copula is another choice with the values of the AIC and the BIC at -55.1766 and -39.4893, respectively. Also, the copula parameters, ω = -0.0413, β = -0.4393, and α = -0.2608, have significance at level 0.00. Hence, the time-varying rotated Joe 180° is chosen.

As for the pair-copula of Crude oil–Soybeans (C,S), it is shown that a time-varying Student's T copula is the best fit with three copula parameters $\omega = 1.0645$, $\beta = 2.1957$, and $\alpha = 0.0164$. Also, all the copula parameters have significance at level 0.00.

Tree 2, a conditional pair-copula of Palm oil–Soybeans given Crude oil (P,S | C), shows that the time-varying Student's T is the best fit with the copula parameters $\omega = 0.0180$, $\beta = 1.9274$ and $\alpha = 0.0338$. Also, all the copula parameters have significance at level 0.00.

The parameter α of all the pair-copulas have significance, indicating that the values of dependence between each pair of the commodity prices, that is Crude oil–Palm oil, Crude oil–Soybeans and Palm oil–Soybeans given Crude oil, keep varying over time. Moreover, Crude oil–Soybeans shows that it has the highest degree of persistence in the dependence, as indicated by the parameter β. The comparisons between the values of dependence of the static copulas and the time-varying copulas are shown in Figure 3.3 It can be seen that the values of dependence have fluctuated significantly through time.

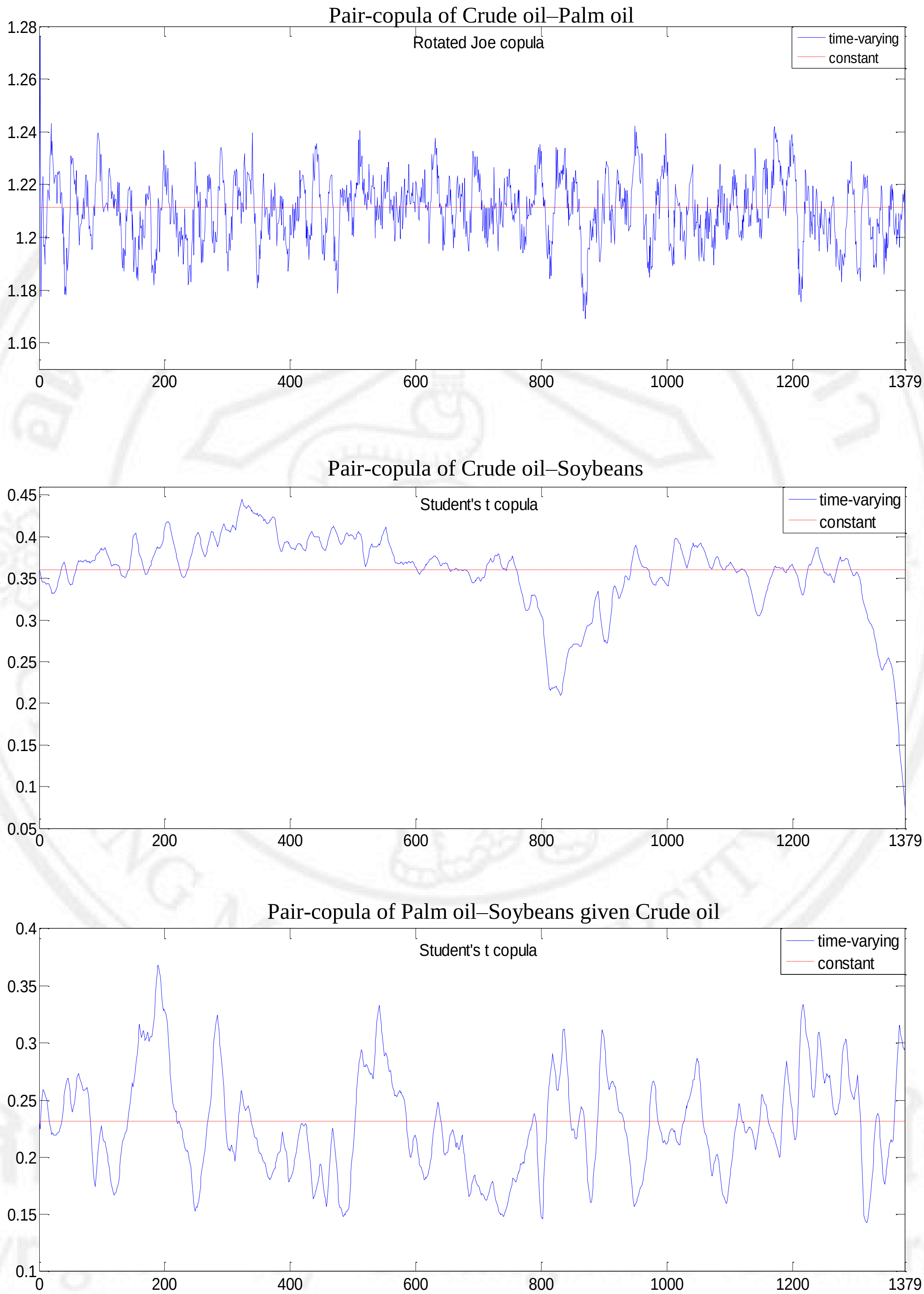

Figure 3.3 The time-varying of the pair-copulas

3.5 Discussion and Policy Implications

For discussion in relationship between energy prices and two food prices, that is, the prices of crude oil, palm oil, and soybeans. The results of a bivariate copula analysis between each price were used in this part. The relationships considered are Crude oil–Palm oil, Crude oil–Soybeans, and Palm oil–Soybeans. Our results show that there exists a weak positive dependence in each pair-copula and that their dependences keep varying over time. The commodity prices of each pair tend to move together. As they simultaneously traverse upward and downward, the dependency hangs on whether the market is booming or crashing.

The first pair-copula, Crude oil–Palm oil, shows that the Gaussian copula is the best fit with a copula parameter 0.2495 and Kendall's tau correlation at 0.16. There exists a weak positive dependence between crude oil and palm oil, it indicates that an increase or a decrease in the palm oil prices is slightly related to the crude oil prices. This phenomenon can be explained using the following reasons: First, in the ASEAN region, palm oil can be produced sufficiently for the intra-regional demand and the remaining volume can be stored for export. Second, the countries in ASEAN region have only a small proportion in the consumption of biofuels when compared to the consumption of the other energy resources. The U.S. Energy Information Administration (2013a) reported that in 2010, the Thailand energy consumption of biofuels was just 0.7% of the total consumption of energy from various sources. Third, only a small proportion of palm oil was used for biodiesel production when we consider the total production of palm oil that reaches the markets. With regard to the average import quantity of palm oil during the season 2008/2009–2012/2013, India was in the first place with 7,220 thousand metric tons (20% of the world total), followed by China with 5,986 thousand metric tons (16%), and EU-27 with 5,438 thousand metric tons (14%) (USDA, 2013a). During the period from 2008 to 2011, India and China had average production capacities of biodiesel at 1.3 and 6.2 thousand barrels per day, respectively, which was less than Thailand which had an average of 9.85 thousand barrels per day (U.S. Energy Information Administration, 2013b). Although the import quantities of palm oil for China and India during the season 2008/2009–2012/2013 were more than the domestic consumption of palm oil of Thailand, which was 4–5 folds (USDA, 2013a), the production capacities of biodiesel per day of these countries remained low when compared to that of Thailand. This indicates that most palm oil exports to China and India are not used for biodiesel production. The raw materials for biodiesel production are different in different countries. As for the main biodiesel producer countries, such as the European nations and the USA, they use rapeseed oil and soybean oil, respectively, to produce biodiesel. Argentina and Brazil use soybean oil, and Malaysia and Indonesia use palm oil for biodiesel production. India, China, and several Sub-Saharan and Southeast Asia countries have promoted jatropha biodiesel (Gasparatos et al., 2013). In recent years, with a rise in production capacity, ASEAN has expressed an interest in biofuels: this development is shown in Table 3.8 and Table 3.9. The increasing proportion of biofuels requires a long time for adaptation with regard to the terms of production, distribution, and consumption. From all of the above-mentioned figures, it can be said that the palm oil market in ASEAN has not been severely affected by the demand for alternative energy even though there was a period where crude oil prices had volatility and a constant rise in cost. Therefore, we found that the palm oil prices are slightly related to the crude oil prices.

Table 3.8 and Table 3.9 present the biodiesel and the fuel ethanol production per day during the period 2002–2011 of the ASEAN countries, Europe, and USA (U.S. Energy Information Administration, 2013b, 2013c). This shows that both America and Europe are more progressed than ASEAN in the production of both types of biofuel. For ASEAN and Europe, a proportion of biodiesel production is higher than that of ethanol; however, in the case of USA, ethanol has a higher proportion. There are various kinds of food crops that can be used to produce biofuels. Ethanol is produced mainly from corn and sugarcane, while biodiesel is produced mainly from vegetable oils. In Europe and the USA, biodiesel is mainly extracted from rapeseed oil and soybean oil, respectively (Serra and Zilberman, 2013).

Table 3.8 Biodiesel Production (Thousand Barrels Per Day)

Boundary	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
ASEAN	0.00	0.00	0.00	0.82	2.60	6.00	17.30	24.00	24.30	34.20*
Europe	24.30	32.63	41.10	62.06	96.52	122.39	150.69	173.87	183.14	177.69
USA	0.68	0.93	1.82	5.92	16.34	31.95	44.11	33.65	22.40	63.11

Source: U.S. Energy Information Administration (May 2013).
Note: *The 2011 data do not include the data of production of Vietnam.

Table 3.9 Fuel Ethanol Production (Thousand Barrels Per Day)

Boundary	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
ASEAN	0.00	0.00	0.10	1.20	2.30	3.20	5.91	8.24	8.88	10.50*
Europe	5.00	6.70	7.75	14.76	27.34	31.41	47.36	59.31	72.10	72.80
USA	139.61	182.94	221.47	254.69	318.61	425.38	605.57	713.49	867.44	908.62

Source: U.S. Energy Information Administration (May 2013).
Note: *The 2011 data do not include the data of production of Cambodia.

The second pair-copula, Crude oil–Soybeans shows that the Gaussian copula is the best fit with a copula parameter 0.3545 and Kendall's tau correlation of 0.23. This pair-copula provides stronger dependence than the first pair of Crude oil–Palm oil because of the following reasons. First, USA uses soybean oil as the major material for biodiesel production, as is the case with Brazil and Argentina. During the season 2008/2009–2012/2013, USA, Brazil, and Argentina were the largest producers and exporters of soybeans in the world: they ranked first, second, and third, respectively (USDA, 2013b). During 2008–2011, these three countries had average production capacities of biodiesel at 40.82 (12.5% of the world total), 33.74 (10%), and 30.09 (8.8%) thousand barrels per day, respectively (U.S. Energy Information Administration, 2013b). Thus, the demand for soybean oil for the production of biodiesel will have an effect on the soybeans prices. Second, ASEAN has to import soybeans from outside the region, and face an import competition and a price competition with other countries such as China and EU-27. During the seasonal period of 2008/2009–2012/2013, China and EU-27 were the largest importers of soybeans in the world and were ranked as the first and the second, respectively. The average import quantities were 52,401 thousand metric tons (59% of the world total) for China and 12,463 thousand metric tons (14% of the world total) for EU-27. Additionally, China tended to import soybeans in large proportions but the EU-27 showed a propensity to decrease the imports. As for ASEAN, during the season 2008/2009–2012/2013, the average import quantity was 4,382 thousand metric tons (4.9%) and it tended to import soybeans in great proportions, just like China (USDA, 2013b). Similarly, as mentioned by Abbott et al. (2011), the increase in soybeans importation by China has an effect on soybean prices.

Because of the reasons mentioned above, we found that a high demand of soybean for both biofuel production and consumption makes the correlation between the crude oil prices and the soybeans prices stronger than the correlation between the crude oil prices and the palm oil prices.

For the third pair-copula, Palm oil–Soybeans (P,S), we found that there exists a weak positive dependence and that the Gaussian copula is the best fit with a copula parameter 0.2970 and Kendall's tau correlation of 0.19. According to the results presented of the conditional pair-copula, these two food prices were both influenced by the crude oil price. The dependence between the palm oil prices and the soybeans prices has a weak dependence because ASEAN had more palm oil production capacity and was the largest exporter in the world. Thus, the movement of the palm oil prices has less volatility than that of the soybeans prices because ASEAN had to import soybeans from outside the region. Soybeans were used as raw material for various food and biodiesel productions, thereby causing more volatility in the soybean prices. This is consistent with the descriptive statistics that was presented in Table 3.1, which showed that the growth rates of the soybeans prices had a higher volatility than the growth rates of palm oil prices, made evident by the higher values of skewness and kurtosis: soybean's values were -0.8990 and 23.50, and palm oil's values were -0.3472 and 7.03, respectively.

According to the first objective, the findings show that the volatility of the crude oil benchmark prices of the ASEAN (Dubai price) has dependence on the soybeans prices (CBOT price) which was stronger than the palm oil price (MDEX price).

In terms of energy security, the results of the analysis showed that these two food commodities have not been used as biofuel to produce biodiesels on a very large scale when we consider the total output volume of both these food commodities which were produced and put into the market. Palm oil and soybean oil can be used to produce biodiesel as an alternative energy for substitution when the crude oil price is high or when there is a shortage of crude oil. However, if either palm oil or soybean oil, or both are used too much for biodiesel production, then it will have an effect in raising the dependence between the crude oil prices and the prices of these food commodities. The consequence will be an increase in the prices of these food commodities. A rise in food prices and energy prices will have an impact on the people living in the ASEAN region and in other parts of the world because both these goods are very important commodities. Thus, it has to be made sure that it is balanced.

In terms of food security with regard to the demand of soybeans in ASEAN, there must be a total effort to reduce the risk of rising soybeans prices which is stemming from the oil price rises or other factors, by having ASEAN cooperate in unity in order to reduce soybean imports from the outside region through an increase in the output production using various innovative ways — for example, plant breeding, culture control, expansion of cultivated area, agriculture extension, etc. In this regard, there is a good model in place in Indonesia where there is a plan to raise Indonesia's import duty on soybeans by up to 20%; the money collected from the higher duty will be used to subsidize tempeh and tofu makers, and to push them to purchase local soybeans and boost domestic soybeans production (USDA, 2013e). For Thailand, maize can be an example for reducing the imports of agricultural commodities from the outside region by promoting the cultivation of maize in Cambodia, Myanmar, and Laos through contract farming. This idea can be implemented by facilitating the custom border service, managing the logistics and transportation development, and reducing tax under the framework of Ayeyawady-Chao Phraya-Mekong Economic Cooperation Strategy (ACMECS) (Thai-AEC, 2012). Thus, the establishment of an AEC will have a positive effect on the agriculture of food crops and energy crops because it will facilitate the movement of production factors and their goods. However, to promote an increase in the cultivated area of food crops and energy crops, the allocation of the cultivated area should be balanced between the different crop types for a variety of agro ecosystems. In addition, the policy makers should prevent and control forest loss and degradation alongside their endeavor to bring about an increase in the cultivated area.

According to the second objective, the results from vine copula indicate that there exists a weak positive dependence between palm oil prices and soybeans prices, given crude oil prices as a conditioning variable. The Gaussian copula is the best fit with a copula parameter 0.2303 and Kendall's tau correlation of 0.15. By doing a comparison between a conditional pair-copula (P,S | C), given in Table 5, and a bivariate pair-copula (P,S), given in Table 6, we found out that our results show that the copula parameters and the Kendall's tau correlations of a conditional pair-copula (P,S | C) in all the copula families are less than those that were obtained from the bivariate pair-copula (P,S). This implies that crude oil price has an influence on the relationship between palm oil price and soybeans price. The crude oil price is an important variable that governs the interactions in the dependence structure between the palm oil price and the soybeans price. The increase (decrease) of crude oil price has an influence to both palm oil and soybeans price.

Considering to a bivariate pair-copula, Palm oil–Soybeans, we found that there exists a weak positive dependence and that the Gaussian copula is the best fit with a copula parameter 0.2970 and Kendall's tau correlation of 0.19.

In terms of energy security for both the foods, the results show that in the past the prices of both the foods have showed weak positive dependence, or an increase (decrease) in palm oil prices is slightly correlated by an increase (decrease) in soybeans prices, or vice versa. For biodiesel production, if the price of one food commodity rises to a high level, we may use the other one which has a slight co-movement of price (or lower price) as a substitute. However, different food types have different characteristics for biodiesel production, and so, policy makers should take into consideration the suitability for food security, environment, social situation, etc. (Gasparatos et al., 2013).

In terms of food security, a weak positive dependence of these two foods is advantageous to those who are in poverty or are financially disabled because (1) if the prices of both the foods decrease simultaneously, poor people can have access to these foods more easily and (2) even if, and when, the prices of both these foods increase, because of the weak dependence, the intensity of the co-movement of their prices will be less. Those living in poverty can have a choice in the consumption of food or the agricultural products because of the lower prices. For example, they can select the cooking oil which is produced from palm or soybean. As for ASEAN, to reduce the risk or effect from the change in both palm oil and soybeans prices (due to several factors such as natural disasters, increase in demand due to population or economic growth, increase in the cost of production, etc.), ASEAN must have appropriate plans or other initiatives in place. It is good to learn that ASEAN's projects have already been implemented, the projects range from a management information system for agricultural products to human resource development and better knowledge of food security (AFSIS, 2013).

The findings of this study show that the three commodities have a positive dependence on each other. As regards the supply chain of goods and services, the increase of energy prices and food prices are the raw materials in the upstream system which can cause price transmission and volatility spillovers by a sequence from upstream to downstream of the supply chain. This is especially so for those who are almost poor or poor; they will become impacted either directly or indirectly, or both from such an ordeal. The reports from the ASEAN Secretariat (2010) found that the almost poor and the poor were together a risk group which was affected to a large extent by the global financial crisis combined with the food and fuel crises in 2008. According to the Asian Development Bank (2011), there exists an impact of increase in food price on poor people in the 25 Asian developing countries; 7 countries in ASEAN are on the list. The data shows that an increase in food prices by 10%, 20%, and 30% would cause corresponding increases in the percentage of the poor people of by 1.9%, 3.9%, and 5.8%, respectively, or 64.41, 128.83, and 193.24 million in number. Thus, Asian countries should have the tools to balance and reduce price transmission between crude oil prices and food prices that are both direct and indirect. This can be done through methods such as increasing the supply side by promoting the cultivation of food crops in the intra-region, developing the infrastructure for transportation cost reduction, etc. In 2012, the logistics performance index (1=low to 5=high) of Cambodia, Laos, Malaysia, Myanmar, Singapore, Thailand, and Vietnam were 2.56, 2.5, 3.49, 2.37, 4.13, 3.18, and

3.00, respectively (World Bank, 2013).The logistics effectiveness of each country in ASEAN can be further improved upon. For example, Thailand plans to develop the transportation system, such as rails and roads, with an investment of 2.2 trillion Baht in order to improve the performance of these sectors in the country and for it to be linked with the other countries in ASEAN (e.g., ASEAN transport routes from the east to the west for Myanmar, Thailand, Laos, Cambodia, and Vietnam, from the north to the south to include the south of China, Myanmar, Laos, Thailand, Malaysia, and Singapore (Ministry of Finance of Thailand, 2013). Another example is the energy security plan for ASEAN, such as the strategy for transboundary energy networks which has two main components: the Trans-ASEAN Gas Pipeline and the Trans-ASEAN Power Grid (Speed, 2012).

3.6 Conclusions

The AEC plays an important role in the global economy. However, it remains in a state of challenge due to the many problems it faces, such as the global economic recession combined with food and fuel crises, which have an effect on the people who are poor and near-poor in the ASEAN region and can have a negative impact on the social and economic development. The rising prices of food and energy are the challenges for the ASEAN members to overcome. There exist evidences of significant price transmissions between the energy market and the food market. Thus, it is interesting to study the relationship between the crude oil benchmark prices of the ASEAN and the prices of the two food commodities that can be used to produce alternative energy, which are as follows: (1) palm oil, which can be produced and be sufficient for intra-regional demand and (2) soybeans, which relies on imports from outside the region. Gaining an understanding of the dependence structure of these commodity prices will be useful in making decisions and plans for the economic and social development of the AEC.

In this study, the data analyses were based on the daily observations from June 2007 to March 2013. The GARCH model was used to examine the volatility of the future prices 1-Pos. of the three data series and applied the C-vine copula model to examine the relationship between each commodity.

The empirical results of the GARCH(1,1) model with skewed student-T residual show that the crude oil prices, palm oil prices, and soybeans prices have long-run persistence in volatility.

The C-vine copula model was used to study the dependence structure between crude oil price, soybeans price, and palm oil price that related to ASEAN region. This study is interesting to examine an influence of crude oil price on palm oil price and soybeans price. The C-vine copula model is a flexible tool to analyze the relationship between variables, in which the multivariate dependence modeling. It offers us to define the relationship structure between variables according to the purpose of study, and it can describe the relationship between variables through the graphical model or are called pair-copulas, as shown in Figure 3.1 In this study, we assume crude oil price is a condition variable in C-vine structure. The finding results can conclude that the change of crude oil price has an influence on the prices of palm oil and soybeans. Moreover, the findings show that there exists the dependence between palm oil price and soybeans price, and crude oil price is one factor that has an influence on relation of their prices.

The C-vine copula contains three pair-copulas: Crude oil–Palm oil (C,P) and Crude oil–Soybeans (C,S) in the first tree and a conditional pair-copula, Palm oil–Soybeans given Crude oil (P,S| C), in the second tree. For the pair-copula Crude oil–Palm oil (C,P), the Gaussian copula is chosen to explain its dependence structure with a copula parameter of 0.2495 and a Kendall’s tau correlation of 0.16. Similarly, Crude oil–Soybeans (C,S) offers the Gaussian copula as the best fit with a copula parameter of 0.3545 and a Kendall’s tau correlation of 0.23. For the last pair-copula, the conditional pair-copula, Palm oil–Soybeans given Crude oil (P,S| C), the Gaussian copula is chosen to explain its dependence structure with a copula parameter of 0.2303 and a Kendall’s tau correlation of 0.15. Furthermore, considering to a bivariate pair-copula, Palm oil–Soybeans (P,S), we found that there exists a weak positive dependence and that the Gaussian copula is the best fit with a copula parameter 0.2970 and Kendall’s tau correlation of 0.19. This indicates that the price of one commodity is slightly correlated with the prices of the other commodities.

Our results show that the dependence between the crude oil prices and the soybeans prices is stronger than the dependence between the crude oil prices and the palm oil prices due to the increase in biofuel demand and soybeans consumption (Abbott et al., 2011). Moreover, palm oil is produced on a large scale within the intra-ASEAN region, and the ASEAN nations do not have to rely on imports from the outside region. So the price of palm oil is slightly related to the change in crude oil prices. Thus, to reduce the price transmission and volatility spillover between crude oil prices and food prices, and to increase food security, the ASEAN members should get together and cooperate to incorporate innovative and effective plans to increase the capacity and performance in food production in order to reduce the reliance on food imports from outside the region, especially in the case of soybeans.