International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 56.67 | Impact Factor (2017): 5.156

Effect of Climate Change on Palm Oil Production in Malaysia

Wan Noranida WMN[1], Amin MA[2], Ismail AL[3]

Department of Agribusiness and Resource Economics, Faculty of Agriculture University Putra Malaysia, Malaysia

Abstract: ***Climate change has potential to damage irreversibly the natural resource with crucial consequences for agricultural productivity. According to the World Bank, oil palm was the main contributor of Gross Domestic Product (GDP) for Malaysian agriculture. This paper investigated the long run cointegration between the yield of palm oil, labor, planted area, fertilizer, and climate factors such as rainfall and precipitation in Malaysia. An annual time series data was used for the period of 34 years from 1983 to 2016, and Auto Regressive Distributed Lags (ARDL) cointegration approach was employed in achieving the objective of the study. The results revealed the long run models were cointegrated in all parameters. It found that an increase in temperature has a negative impact on palm oil yield. Quantifying the impacts of climate change on palm oil production can help policy makers determine the best adaptation and mitigation measures.***

Keywords: Climate model, economic impact, oil palm, production function, autoregressive distributed lags.

1. Introduction

Climate change refers to any significant change in the measures of temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer. It's due to natural causes and created by human. The climate change has potential to damage irreversibly the natural resource with detrimental consequences for agricultural production. It affects agriculture in a number of ways, including enhance pests and diseases, changes in atmospheric carbon dioxide, and increase the risk of land degradation (Hoffmann, 2013). It also has significant impact for economic development and trade of developing countries particularly those largely rely on agriculture. According to the World Bank, agricultural sector contributes about 9.06% of Malaysian GDP in 2014, where oil palm was the main contributor of GDP for agriculture which covered more than 70% of the agricultural land in the country. Based on Economic Transformation Program (ETP), palm oil industry will raise its GNI contribution from the current RM52.7 billion to RM178 billion by 2020 (Ng et al, 2011) and it was planted to replace other major tree crops.

Palm oil is a highly valuable commodity, which is obtained from the flesh fruit of the oil palm species *Elaeisguenensis.* Malaysia plays an important role in fulfilling the global demand of oil as it accounts for 12% of the world's oils and fats production and 27% of export trade in oils and fats (MPOC, 2016). The expansion of oil palm plantation increases year by year, with the demand of this edible oil, which has impacted in the economic, social and environment. A summary of cultivated area of oil palm is reported in Figure 1. Even though palm oil has spread throughout more than 43 countries, the global production is mainly controlled by Malaysia and Indonesia due to both countries has favorable condition for the well growth of palm oil tree (Sheil et al, 2009). Oil palm is best to thrive with a maximum temperature range between 29 degrees Celsius to 33 degrees Celsius and a minimum temperature range between 22 degrees Celsius to 24 degrees Celsius (Basiron, 2007). It requires a minimum rainfall around 1,500 mm per year with an absence of dry season to favor the highest yield (Corley, 2003). The oil palm tree is sensitive to in two scenarios: drier weather that causes drought and heavy rainfall that leads to flooding (Ramadasan et al, 2001 & Baharuddin, 2007). "El Nino" and “La Nina” are the most important events that give effect to the distribution and production of palm oil. Oil palm plantation in Malaysia was dominated by Sarawak, Sabah, Johor, Pahang and Perak. However, in 2016, the contribution of oil palm sector has declined due to the impact of El Nino occurred in these states (Department of Statistics, Malaysia, 2016). Figure 2 reported a trend of palm oil production from 1992 until 2016. The higher rainfall of the La Nina decreased the production and quality of crude palm oil, thus affecting the fruit ripening stage, and reflected in the yield in subsequent months (Paterson et al, 2018).

The Malaysian Meteorological Department has employed high detailed regional analysis of Providing Regional Climates for Impacts Studies (PRECIS) simulation driven by the Atmosphere-Ocean General Circulation Models (AOGCMs) to generate future climate change for three decades represented by first quarter (2020 – 2029), middle (2050 – 2059) and end of the century (2090 – 2099) relative to 1990-1999 period. The results indicate that Malaysia will experience rise temperature in range 1.0 to 1.5 degrees Celsius for the first quarter and increase in range 1.7 to 2.0 degrees Celsius in middle period. The temperature is estimated increase in range 2.8 to 3.8 degrees Celsius at end of century and generally higher temperature is simulated for East Malaysia compared to Peninsular Malaysia. On the other hand, more rainfall is simulated during the last decade for the whole country compared to the first and middle quarter century. Overall, Peninsular Malaysia is expected to see increase in annual rainfall by 4.1% to 15.2% compared to East Sabah with a negative anomaly for rainfall pattern.

Talib (1988) has conducted an analysis of supply response on palm oil production in Malaysia. However, it only focused on price incentives, and not considered climatic factors. Zainal et al (2012) has applied Ricardian approach found that climate change has significant nonlinear impact on net revenue. Shanmuganathan et al (2012) has attempted to model the climate change on Malaysia's oil palm yield, however, the precise temperature, the critical magnitude, and its lagged effects on oil palm yield could not be identified due to a small sample set of yield data used. Realizing the scarce of empirical studies to predict the impact of climate change on Malaysia's oil palm yield, this study focused extensively to model the effect of climate change by applying production function approach. Other approaches might gain a better estimate, hence add to the current literature. The finding of the study will provide a basis for further policy and adaptations.

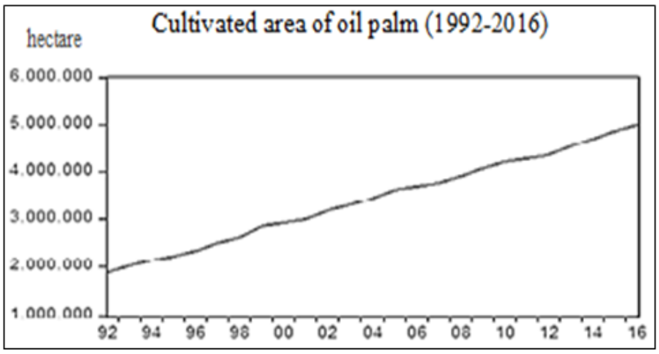

Figure 1: Cultivated area of oil palm in Malaysia

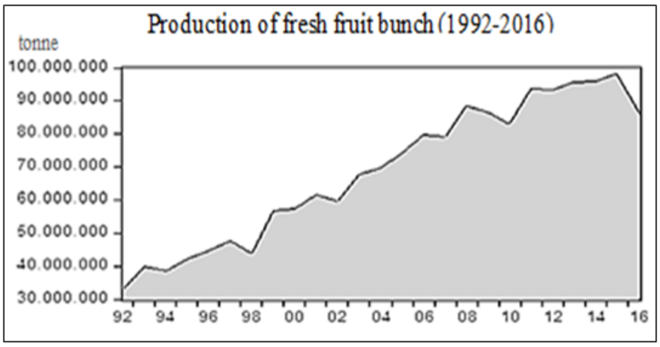

Figure 2: Production of fresh fruit bunch

2. Materials and Methods

2.1 Study area and data

The location of the study covered Peninsular Malaysia, Sabah and Sarawak. The study area is about 131,598 square kilometers of all 14 states. Average annual climate data including precipitation (mm) and temperature (degree Celsius) were from Department of Meteorology Malaysia. Some data on yield, labor and cultivated area retrieved from Department of Statistic (DOS), Malaysia database. Other data obtained from Malaysia Palm Oil Board (MPOB) and Malaysia Palm Oil Council (MPOC) from period 1983 to 2016.

2.2 Theoretical Framework

A Cobb Douglas production function is explaining the technical relationship between input and output, in which two important factor inputs; labor and capital determine the level of total output in production. This relationship can be expressed in Cobb Douglas production function as follows:

$$Q = f\left(AL^{\alpha}K^{1-\alpha}\right) \qquad (1)$$

An extended Solow growth model can be developed by introducing other factor inputs such as mature area of oil palm (M) that can influence the total output (Q) in addition to labor and capital and holding other factors constants (all things being equal). This model can be specified as:

$$Q = f\left(AL^{\alpha}M^{\beta}K^{1-\alpha-\beta}\right) \qquad (2)$$

From equation (1) and (2) above, Q stands for yield of fresh fruit bunch that depends on the function of factor inputs; (L) as labor input, (M) as mature area of oil palm, (K) is capital and proxy to fertilizer used, and (A) is the level of technology. Likewise α, β and $1-\alpha-\beta$ are the coefficients of labor, mature area and capital in which their summations is equalled to one. The linear function can be specified as:

$$In\,Q = f\,In(AL, M, K) \qquad (3)$$

Equation (4) is an econometric model that generated from equation (3) by adding an intercept of the slope (α_0) and the disturbance variable (μ):

$$In\,Q = \alpha_0 + \beta_1 InL + \beta_2 InM + In\beta_3 InK + \mu \qquad (4)$$

Additionally, subscript (*t*) can be added to each variable with the exception of intercept (α_0) to present time series model:

$$In\,Q = \alpha_0 + \beta_1 InL_t + \beta_2 InM_t + In\beta_3 InK_t + \mu_t \qquad (5)$$

Oury (1965) consolidated the ideas of the earlier studies and has applied climate variables (temperature and rainfall) as auxiliary factors that affect production process. Hence, we have:

$$In\,Q = \alpha_0 + \beta_1 InL_t + \beta_2 InM_t + In\beta_3 InK_t + In\beta_4 InT_t + In\beta_5 InR_t + \mu_t \qquad (6)$$

R^2 and T^2 can be added to enable us to estimate the quadratic effect of the climate variable in order to achieve the objective of the study.

$$In\,Q = \alpha_0 + \beta_1 InL_t + \beta_2 InM_t + \beta_3 InK_t + \beta_4 InT_t + \beta_5 InT^2{}_t + \beta_6 InR_t + \beta_7 InR^2{}_t + \mu_t \qquad (7)$$

2.3 Model Specification of Yield

Three different specifications were tested; temperature in the first specification, precipitation in the second specification, and both temperature and precipitation as indicators of climate change in the third specification.

Model 1

$$In\,Q = \alpha_0 + \beta_1 InL_t + \beta_2 InM_t + \beta_3 InK_t + \beta_4 InT_t + \beta_5 InT^2{}_t + \mu_t$$

Model 2

$$In\,Q = \alpha_0 + \beta_1 InL_t + \beta_2 InM_t + \beta_3 InK_t + \beta_4 InR_t + \beta_5 InR^2{}_t + \mu_t$$

Model 3

$$In\,Q = \alpha_0 + \beta_1 InL_t + \beta_2 InM_t + \beta_3 InK_t + \beta_4 InT_t + \beta_5 InT^2{}_t + \beta_6 InR_t + \beta_7 InR^2{}_t + \mu_t$$

Where;
Q = Yield of fresh fruit bunch (tonne)
L = Labor
M = Mature area of oil palm (hectare)
K = Capital (proxy to fertilizer)
T = Temperature (degree Celsius)
R = Rainfall (millimetre)

3. Results and Discussion

The models were selected based on the basis of the Schwartz-Bayesian Critieria (SBC) and Akaike's Information Criteria (AIC). The climate equation for model 1 was determined by the lagged one and lagged two years annual yield adjusted, labor, area, capital, temperature in lagged one and temperature square in lagged one and two. While, for model 2, it was expressed by the lagged one year annual yield adjusted, labor, area, capital in lagged one, rainfall and rainfall square. For model 3, the equation was lagged one year annual yield adjusted, labour, area, capital, temperature, temperature square, rainfall and rainfall square.

A unit root test was conducted to determine the stationarity of the data. From table 1, is the result of an Augmented Dickey Fuller (ADF) and Phillip Perrons (PP) test. The results reported that InM, InR and InRS were stationary at 1% significant level, while InK was stationary at 10% significant level. Others such as InQ, InL, InT and InTS were stationary at first difference. Thus, the mixture of stationary and stationary at first difference gives a basis of conducting ARDL approach to cointegration.

Table 2 presented F- statistic results for all models were greater than F-tabulated at 1% significant level. Therefore, this gives a basis to proceed with the estimation of long run models respectively.

Table 3 showed the long run coefficient of cultivated area was positive, elastic and statistically significant at 1% level for model 1. An increase of 1% in area would result in the increasing per tonne of fresh fruit bunch about 1.35% for model 1, 0.79% for model 2 and 1.14% for model 3. The labor has expected positive sign, and statistically significant at 1% level for model 2. An increase of 1% in labor would result in the increasing per tonne of fresh fruit bunch about 0.24%. The long run coefficient for capital, rainfall and rainfall square recorded insignificant for all tested models. The long run coefficient of temperature has expected negative sign and statistically significant at 1% level for model 1 and statistically significant at 5% for model 3. An increase of 1 degree Celsius in temperature would result in the decreasing of 4.92% and 1.96% per tonne of fresh fruit bunch for model 1 and model 3, respectively.

Table 1: ADF and PP unit root tests

Variable	ADF		PP	
	Level	First Difference	Level	First Difference
InQ	-1.74	-6.71***	-1.58	-10.14***
InL	-1.33	-4.96***	-1.36	-4.93***
InM	-5.23***	-3.90***	-7.34***	-3.819***
InK	-3.36*	-10.21***	-3.31*	-10.21***
InT	-0.69	-7.41***	-2.41	-14.86***
InTS	-2.46	-6.53***	-2.36	-9.56***
InR	-5.07***	-8.95***	-5.09***	-9.31***
InRS	-5.07***	-9.03***	-5.07***	-9.43***

Notes:*, ** and *** denote significance at 10%, 5% and 1% respectively.

Table 2: ARDL cointegration test

Bound test result	K	F-statistics	Narayan (2005) critical values	
			I(0)	I(1)
Model 1	5	19.867***	4.134	5.761
Model 2	5	15.242**	4.134	5.761
Model 3	7	29.343***	3.864	5.694

Table 3: Coefficient of the estimated long run model

Variable	Model 1	Model 2	Model 3
InL	-0.024 (-0.269)	0.247 (2.985)***	0.125 (2.124)**
InM	1.353 (9.818)***	0.789 (6.290)***	1.145 (13.271)***
InK	-0.058 (-0.905)	0.041 (0.376)	-0.053 (0.885)
InT	-4.924 (-2.657)***		-1.965 (-2.219)**
InTS	-1.072 (-1.305)		-1.817 (-3.025)***
InR		1.036 (0.881)	0.717 (0.941)
InRS		-0.433 (-0.734)	-0.390 (0.321)
C	9.631 (4.137)***	-0.484 (0.274)	8.228 (5.048)***
R-squared	0.997	0.992	0.996
Adjusted R-squared	0.996	0.991	0.995
Durbin-Watson stat	2.096	1.802	2.345
F-statistic	805.366	504.911	962.913
Prob (F-statistic)	0.000	0.000	0.000

Notes: Values in parenthesis are the t-statistics; *, ** and *** denote significance at 10%, 5% and 1% respectively.

The diagnostic tests revealed that all models passed all tests. Jarque-Bera test indicated that the residuals were normally distributed, Breusch-Godfrey Serial Correlation LM test rejected the present of serial correlation, and Breusch Pagan Godfrey test did not indicate any evidence of heteroscedasticity of the residuals and Ramsey RESET test showed no evidence of functional form misspecification (Table 4).

Table 4: Diagnostic tests

Test	Model 1	Model 2	Model 3
Normality	2.17 (0.330)	2.742 (0.253)	1.149 (0.562)
Serial Correlation	0.31 (0.730)	0.129 (0.878)	1.755 (0.201)
Heteroskedasticity	1.23 (0.260)	0.391 (0.937)	0.787 (0.671)
Functional Form	0.06 (0.810)	0.617 (0.439)	0.126 (0.726)

4. Conclusion and Policy Implications

The yield of palm oil and its determinants; cultivated area, labor, fertilizer, rainfall, and temperature are cointegrated. Model 3 was chosen for the production function approach. For climatic factors, temperature is the most significant factor compared to rainfall that affects the yield of fresh fruit bunch for the long run. The result showed that climate variable, especially temperature have negative impact on palm oil yield. Adaptation measures, such as developing new varieties that are more tolerant to high temperature, which could be supported by encouraging research and development (R&D) efforts, increasing investment in palm oil cultivation, and developing proper adaptation programs or policies, will be necessary to effectively respond to climate change. Based on the negative effect of climate change on palm oil yield and the extensive nature of investments in this sub-sector, more detailed studies are required especially on other factors such as evapotransipiration, soil water storage, and greenhouse gas emission that play vital roles in determination of agricultural production in future.

References

[1] Basiron, Y, 2007. ‘Palm oil production through sustainability plantations’, *European Journal Lipid Science Technology*, 109:289-295.

[2] Baharuddin, M.K, 2007. Climate change – Its effects on the agriculture sector in Malaysia. National Seminar on Socio-economic Impact of extreme weather and climate change. 21-22.

[3] Corley, R.H., & Tinker, P.B (2003). World Agriculture Series: The Oil Palm. Blackwell Science. Oxford

[4] Department of Statistics, Malaysia, (2016). Malaysia Economic Statistic: Time Series 2016.

[5] Hoffmann, U, 2013. Agriculture at the crossroads: Assuring food security in developing countries under the challenges of global warming. Key. Trade and environment review.

[6] Malaysia Palm Oil Council (MPOC), 2016. ‘Overview; Oil Palm’. Malaysian Palm Oil Industry, Malaysia.

[7] Malaysian Meteorological Department, (2009). ‘Climate change scenario for Malaysia’. Malaysian Meteorological Department, Malaysia.

[8] Ng, Y.N., Yew. F, K., Basiron, Y., & Sundram, K. (2011). A Renewable Future driven with Malaysian palm Oil Based Green Technology. Journal of Oil Palm & The Environment 2011, 2:1-7.

[9] Oury, B. (1956). Allowing for weather in crop production model building. Journal of Farm Economic, Vol. 7 No.2, pp. 270-283.

[10] Paterson, M., & Lima, N. (2018). Climate change affecting oil palm agronomy, and oil palm cultivation increasing climate change, require amelioration. Ecology and Evolution. Volume 8, Issue 1.

[11] Ramadasan, K., Mohamad Zabawi, A.G., Yew, F.K., Mohamad Yusof, A., & Hawa, Z.J, 2001. Assessment of the impacts of climate change on key economic sectors in Malaysia agriculture. Minister of Science, Technology and Environment, Malaysia.

[12] Shanmuganathan, S., & Narayanan. A. (2012). Modeling the Climate Change Effects on Malaysia’s Oil Palm Yield. Geoinformatics Research Centre.

[13] Sheil, D.C., Meijaar, E., &Kannien, M. (2009). The Impacts and Opportunities of Oil Palm in Southeast Asia. Centre for International Forestry Research, Bogor, Indonesia.

[14] Talib, B.A. (1988). Supply Response Analysis of Palm Oil in Malaysia 1961-1985. Jurnal Ekonomi Malaysia 18. 43-55.

[15] United States Department of Agriculture (USDA). (2015). Malaysia: 2014/2015 Palm oil Production Affected by Flooding. Commodity Intelligence Report.

[16] Zainal, Z., Shamsudin, M.N., Mohamed, Z.A., & Adam, S.S. (2012). Economic Impact of Climate Change on the Malaysian Palm Oil Production. Trends in Applied Science Research 7 (10):872-880.

Appendix

The results from CUSUM and CUSUMSQ indicate that the absence of any instability of the coefficient because the plot of the statistic fall inside the critical bands of the 5% confidence interval of the parameter stability (Figure 1, 2, 3, 4, 5, 6).

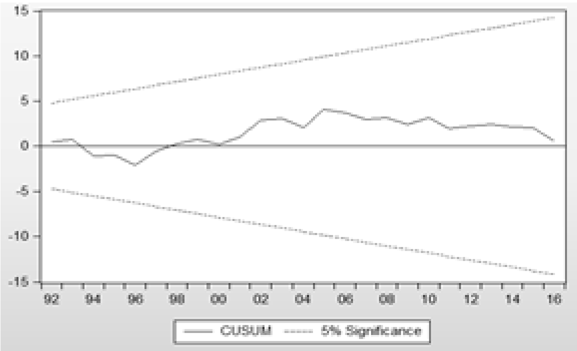

Figure 1: CUSUM test of palm yield model 1

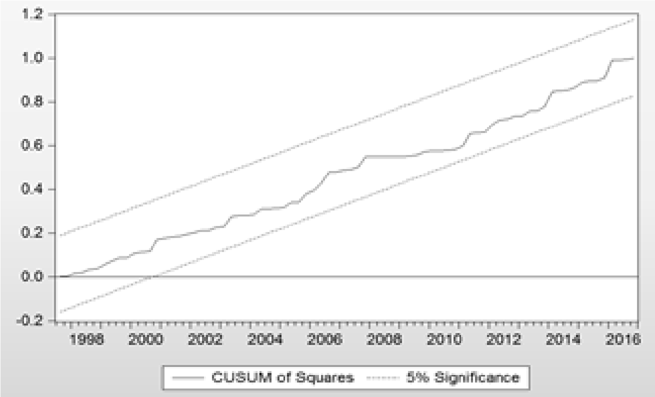

Figure 2: CUSUM Square test of palm yield model 1

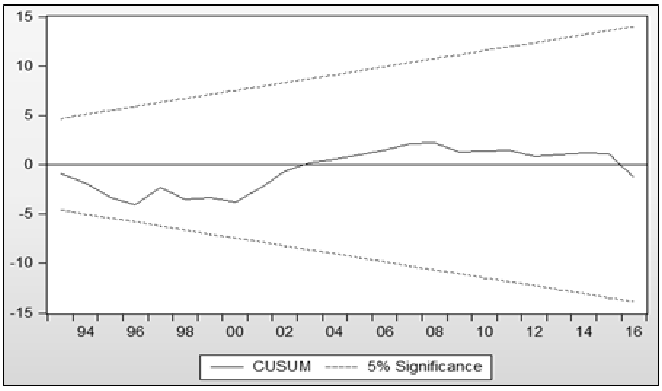

Figure 3: CUSUM test of palm yield model 2

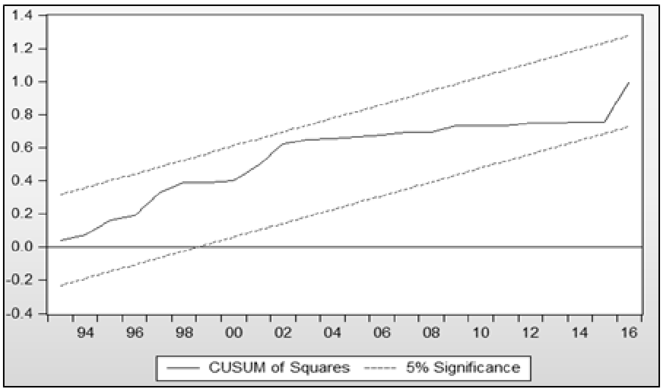

Figure 4: CUSUM Square test of palm yield model 2

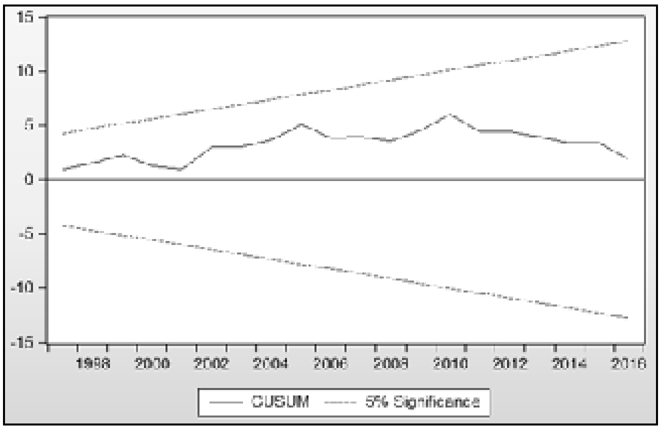

Figure 5: CUSUM test of palm yield model 3

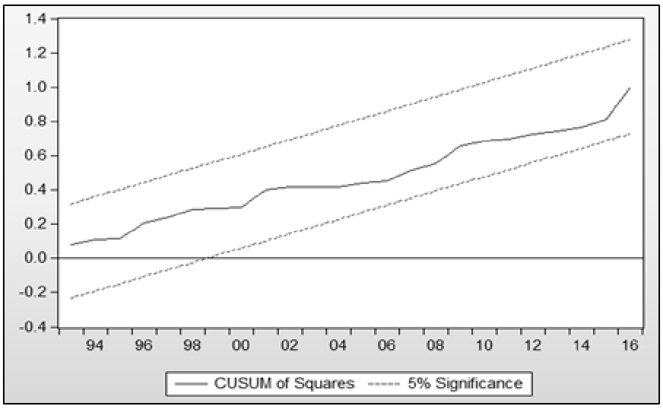

Figure 6: CUSUM Square test of palm yield model 3