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# Supply Response Analysis on the Impact of Climate Change on Oil Palm Production in Malaysia

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**Abstract.** Climate change has significantly impact the economic development and trade of developing countries particularly those largely rely on agriculture. According to the World Bank, oil palm was the main contributor of GDP for Malaysia agriculture. Climate change affects oil palm growth and productivity in a number of ways, including reduction in sex-ration, disrupts the pollination process, abortion of newly produced inflorescence, drops in productivity, and increase in ranges and distribution of pests and diseases. Much of the economic researches devoted to employ production function and Ricardian approach. This study, therefore, focuses to model the effect of climate change on oil palm production by using supply response approach. An annual time series data used for the period of 37 years starting from 1980 until 2016, and Autoregressive Distributed Lags (ARDL) co-integration -employed in achieving the objective of the study. Six econometric models consisting of linear and non-linear equations were constructed by incorporating temperature and rainfall as proxies for climate variable to estimate the yield response model. The results revealed that oil palm production was very negatively affected by changes in temperature compared to changes in rainfall. Meanwhile, the planted area and own price upsurge the supply of palm oil. The results also indicated that Model 3 and Model 6 were the best model to represent the linear and non-linear effect of climate change on oil palm production, respectively. Quantifying the impact of climate change on palm oil production can help policy makers and relevant stakeholders to determine the best adaptation and mitigation measures.

**Keywords:** Climate Change, Oil Palm Production, Supply Response, ARDL

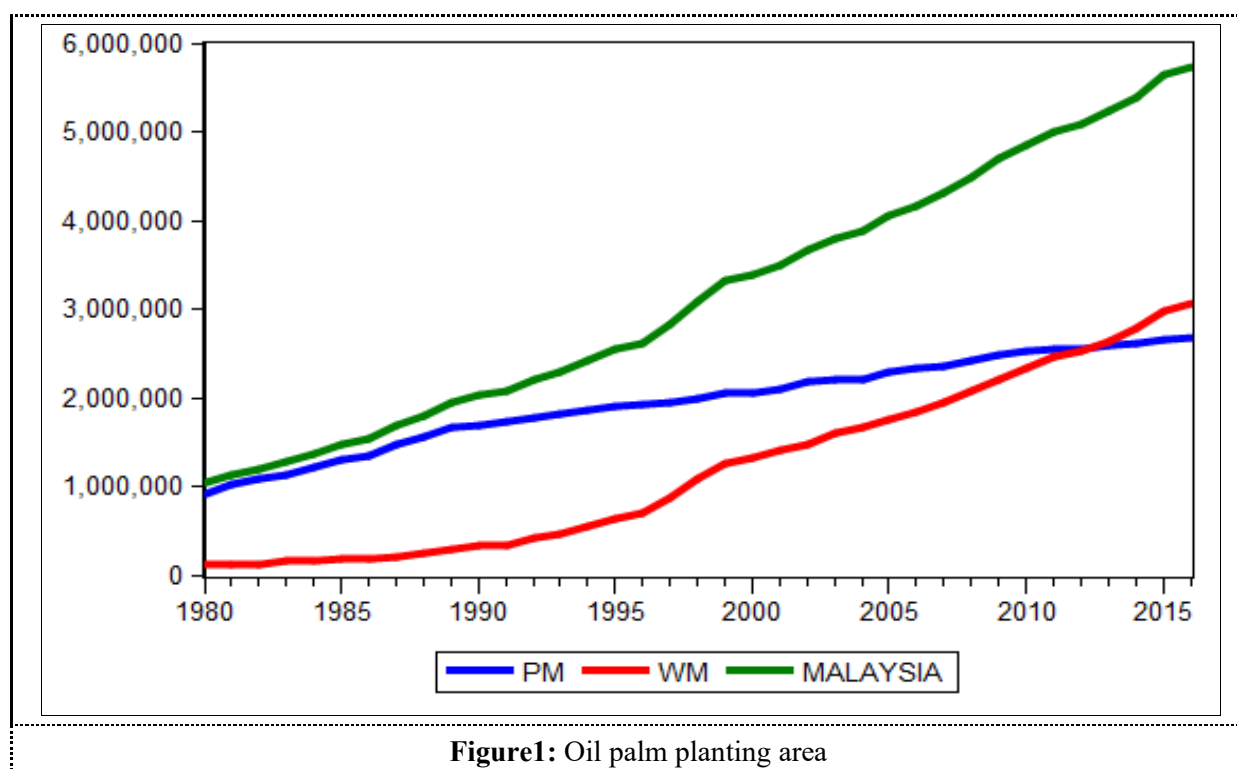
## 1. Introduction

Agriculture is the foundation of a developing country's economy. The agriculture sector presents its average value of RM22,310.81 million from 2010 until 2016, reaching a high of RM26,665 million in the third quarter of 2015 and record a low of RM19,362 million in the first quarter of 2011 [1]. The contribution of agriculture to the Gross Domestic Product (GDP) increased from 7.3 percent in 2010 to 9.2 percent in 2014. The crops sub-sector was the main contributor of GDP for agriculture, accounting for more than 52 percent per annum for the period of 2006 until 2010. From that, oil palm got a lot of attention by the Malaysian government because it gives a lot of returns to the national economy. Palm oil is a highly valuable commodity, which it is obtained from the flesh of the fruit of the oil palm species *Elaeisguenensis*. The contribution of palm oil is very significant for the Malaysian economic with the export revenue generated is RM67.6 billion, which is equivalent to 6.1 percent of country's total GDP in 2016 [2]. The expansion of oil palm plantations increases year by year, with the demand of this edible oil, which has impacted in the economic, social and the environment. The oil palm



planting area covered 60,000 hectares by 1960, and it reached 1 million hectares and 4.85 million hectares in 1980 and 2010 respectively [3]. The total oil palm planting areas has been expanding as shown in Figure 1.

The oil palm thrives under tropical climate, which is ideal to Malaysia's temperature and rainfall pattern. Yield becomes productive under a temperature range of 24 to 30°C and receives an average of 2030 mm rainfall per year [4, 5]. However, change in climate such as heavy rainfall and high temperature will give broad scale impacts on the distribution of oil palm. The states that most frequently hit by floods are Pahang, Johor, and Terengganu while Perlis recorded received lowest annual flood frequency in Peninsular Malaysia. Meanwhile, strong El Nino events were recorded in 1982, 1987, 1991 and 1997. During these four years, Western Peninsular Malaysia and Sabah showed higher temperatures than Eastern Peninsular Malaysia and Sarawak [6].



**Figure1:** Oil palm planting area

The Malaysian Meteorological Department (2009) projects an increase in temperature, relative to the present, of between 1.0° to 1.5° Celsius for the first quarter (2020 – 2029), increase in range 1.7° to 2.0° Celsius for the middle quarter (2050 – 2059) and rise further in range 2.8° to 3.8° Celsius at the end of the 21<sup>st</sup> century (2090-2099). Generally, higher temperatures will simulate for East Malaysia compared to Peninsular Malaysia. On the other hand, more rainfall will project during the last decade (2090-2099) for the whole country compared to the first quarter (2020 – 2029) and middle quarter (2050 – 2059) of the century. Overall, Peninsular Malaysia is expected to see increase in annual rainfall by about 4.1 percent to 15.2 percent compared to East Sabah with a negative anomaly for rainfall pattern. The occurrence of adverse weather conditions, do not direct or immediately affect the palm, but reflected in the yield in subsequent months. It is because the climate change affects processes at an earlier growth stage, such as frond production, sex ratio, the extent of floral abortion, the degree of survival of flowers after anthesis and bunch weight [7].

Interest in the impact of climate change on oil palm sector was enormous with numerous specialized researches. [8, 9, 10] explored the impact of climate change on oil palm in term of agronomy and production in Malaysia, while [11] provided mitigation and adaptation strategies towards reducing such impacts. [12] investigated the interrelationship between climate change and oil

palm cultivation, which requires some amelioration methods to sustain the industry and environment. Prior to this, [13] found climate change has significant non-linear impact on oil palm net revenue based on Ricardian approach. Much of the researches on climate change in oil palm sector are devoted to studying the effect of climate change by employing production function and Ricardian approach. Realizing the scarce of empirical studies to estimate the effect of climate change on difference approach, this study, therefore, focuses to model the effect of climate change on oil palm production by using supply response approach. The estimation of agricultural supply response is based on two identified frameworks; the indirect structural form and the direct reduced form. The indirect structural form involves joint estimation of input demand function and supply function. This method is more theoretically rigorous and required detailed information on the quantities and all the input prices. Keeping the view that is difficulty to get the information on price at which the inputs are supplied to the farmers, this study has chosen direct reduced form framework. Further, this study attempts to estimate the magnitude effect of linear and non-linear model of yield response approach in order to close the knowledge gap.

## 2. Research and Methods

The study used an autoregressive distributed lags (ARDL) method to estimate all tested models which consist of three (3) linear model and three (3) non-linear models of yield response approach.

### 2.1 Theoretical Framework of Supply Response Approach

The framework for the use of supply response model varies considerably according to the characteristics of the crops analysed. Some of the models under perennial crops such as the Batement model, the Ady equation, and the Behrman equation. The most prominent directly estimated empirical models shows Nerlovian Partial Adjustment Adaptive Expectation (PAAE) is appropriate to be applied for both seasonal as well as perennial crops [14].

Nerlovian partial adjustment with adaptive expectations model is more realistic because it assumes a progressive and constant adjustment of short-run supply to its long run value, and a recursive formation of price expectations compared to other supply response models. The standard structural form of Nerlove model is:

$$A_t^* = \alpha_0 + \alpha_1 P_t^* + \alpha_2 Z_t + U_t \quad (1)$$

Equation 2.1 describes desired acreage is a function of expected price, an exogenous variable and a disturbance term. The inclusion of a relevant non-market variable, Z, was introduced in Nerlove model as a means of avoiding parameter identification problems [14]. The symbols used for the variables are provided below:

$A_t^*$  = desired acreage at time t

$P_t^*$  = expected future price at time t

$Z_t$  = any other relevant variable at time t

$U_t$  = random residual

$\alpha_0$ ,  $\alpha_1$ , and  $\alpha_2$  = parameters

### 2.2 Model Specification of Supply Response Approach

Agriculture supply response can be measured in term of aggregate acreage under cultivation, output or yield, and total production per acreage unit. The aggregation levels are based on the objective of the study as well as the availability of data. Yield responses were choosing to capture the supply response models with natural logarithmic transformation for both dependent and independent variables. The modification to the basic models was anticipated by the inclusion of exogenous variables such as price of rubber as the proxy for price of substitute crop. The models also were constructed into linear (Model 1-3) and non-linear (Model 4-6). The basic estimation yield equations are as follows:

Model 1:

$$\ln Y = \alpha_0 + \beta_1 \ln PFFB_t + \beta_2 \ln PR_t + \beta_3 \ln A_t + \beta_4 TEMP_t + \mu_t \quad (2)$$

Model 2:

$$\ln Y = \alpha_0 + \beta_1 \ln PFFB_t + \beta_2 \ln PR_t + \beta_3 \ln A_t + \beta_4 RF_t + \mu_t \quad (3)$$

Model 3:

$$\ln Y = \alpha_0 + \beta_1 \ln PFFB_t + \beta_2 \ln PR_t + \beta_3 \ln A_t + \beta_4 TEMP_t + \beta_5 \ln RF_t + \mu_t \quad (4)$$

$R^2$  and  $T^2$  were added to estimate the quadratic effect of the climate variable in order to achieving the objective of the study.

Model 4:

$$\ln Y = \alpha_0 + \beta_1 \ln PFFB_t + \beta_2 \ln PR_t + \beta_3 \ln MA_t + \beta_4 TEMP + \beta_5 \ln TEMP^2_t + \mu_t \quad (5)$$

Model 5:

$$\ln Y = \alpha_0 + \beta_1 \ln PFFB_t + \beta_2 \ln PR_t + \beta_3 \ln MA_t + \beta_4 R + \beta_5 \ln R^2_t + \mu_t \quad (6)$$

Model 6:

$$\ln Y = \alpha_0 + \beta_1 \ln PFFB_t + \beta_2 \ln PR_t + \beta_3 \ln MA_t + \beta_4 \ln TEMP_t + \beta_5 \ln TEMP^2_t + \beta_6 \ln R_t + \beta_7 \ln R^2_t + \mu_t \quad (7)$$

### 2.3 Study Area and Data

All the required data are based on annual basis from 1980-2016 and collected from various sources. Some data on yield of Fresh Fruit Bunch, acreage, price of fresh fruit bunch and price of rubber were retrieved from Department of Statistic Malaysia (DOSM), Malaysia Palm Oil Board (MPOB), and Malaysia Rubber Board (MRB). Acreage refers to the mature area employed for oil palm plantation and its potential to produce FFB. Both yearly mean temperature and rainfall data were sourced from the Malaysian Meteorology Department (MMD). Data were collected and measured based on the following variables:

$y_t$	= Yield of fresh of fruit bunch (ton) in period t
$A_t$	= Mature area of oil palm cultivation (Ha) in period t
$PFFB_t$	= Price of fresh of fruit bunch (RM) in period t
$PR_t$	= Price of rubber (RM) in period t
$TEMP_t$	= Temperature (°Celcius) in period t
$R_t$	= Rainfall (millimeter) in period t
$PF_t$	= Price of fertilizer (RM) in period t

## 3. Results and Discussions

The results and discussions include unit root and co-integration test results, estimated long run and short run coefficients and diagnostic test results of all tested models.

### 3.1 Unit Root Test Results

The standard testing procedures to identify the order of integration of data series were Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test. Table 1 shows that both tests concurred in classifying the following variables as I(1): LFFB (Log of Fresh Fruit Bunch), LA (Log of Area), LPR (Log of Price Rubber) were not stationary in their level from except after first differencing. However, all climate variables; LR (Log of Rainfall), LRS (Log of Rainfall Square), LTEMP (Log of Temperature) and LTEMPs (Log of Temperature Square) were confirmed to be stationary in their level form as indicated by their critical values, which are all significant at 1% level. Meanwhile, the ADF and PP tests' results were conflicting in determining the stationarity for LPFFB (Log of Fresh Fruit Bunch) variable. Further effort was made to determine the stationary property of variable by applying the method of plotting correlogram function of LPFFB as implemented by [15]. It was observed that the trend of correlogram for autocorrelation function has slowly decayed, an indication of a non-stationary process, hence LPFFB variable was treated as an I(1) variable. The results from

Table 1 shows the mixture of stationary I(0) and stationary at first difference I(1) give a basis of conducting ARDL approach to co-integration.

### 3.2 ARDL Co-integration Tests

The F statistics obtained for each of yield model of supply response are shown in Table 2. The results depicted most models were confirmed to be co-integrated which implies the existence of long-run relationship among the variables.

**Table 1:** Results for unit root tests

Variables	Level		First Differencing	
	ADF	PP	ADF	PP
LFFB	-0.073	-0.55	-5.41***	-7.92***
LA	-1.75	-2.27	-4.367***	-4.58***
LPFFB	-4.36***	-3.16	-7.97***	-8.15***
LPR	-2.60	-2.37	-4.54***	-4.91***
LR	-4.16***	-4.74***	-7.34***	-12.15***
LRS	-4.26***	-4.87***	-7.42***	-12.56***
LTEMP	-4.50***	-4.27***	-6.98***	-13.71***
LTEMPS	-4.35***	-5.24***	-6.91***	-13.07***

Note: (\*), (\*\*), and (\*\*\*) denote level of significance at 10%, 5% and 1% respectively

**Table 2:** ARDL co-integration tests

Model Number	K	SIC (Min. Value)	F-Statistic	Narayan (2005) CV at 5%		Remark
				I(0)	I(1)	
1	4	-3.88	6.48	2.86	4.01	Yes
2	4	-4.13	5.92	2.86	4.01	Yes
3	5	-4.33	5.95	2.62	3.79	Yes
4	5	-4.47	3.31	2.62	3.79	Inc.
5	5	-3.81	2.12	2.62	3.79	No
6	7	-3.63	3.59	2.32	3.50	Yes

Note: (\*), (\*\*), and (\*\*\*) denote level of significance at 10%, 5% and 1% respectively. K= Number of exogenous variables in each equation; SIC= Schwarz Information Criterion (Minimum value in each equation); CV= Critical Values at 5% level of significant

The only exception was Model 5 due to F-statistic laid below the lower bound value, hence no long-run relationship among the variables in the equation. The remaining model, namely Model 4 was having inconclusive Bound test. Under inconclusive cases, following [16] and [17] applied the error correction term (which must be negative, less than one and significant) as a useful way of establishing co-integration. The result suggested treating Model 4 as co-integrated model. The lag length selection for each equation was determined using the minimum value of SBC and AIC with a maximum lag order of two.

### 3.3 Coefficient of the Estimated Long-Run Model

The optimal lag structure that generated from the minimum Akaike's Information Criterion (AIC) and Schwarz Bayesian Criterion (SIC) has resulted the ARDL (10100), ARDL (12010), ARDL (121012), ARDL (1,0,1,0,0,1) and ARDL (2,0,1,0,0,0,0,0) specifications, for Model 1,2,3,4 and Model 6,



respectively. The estimation results from all models showed mature oil palm planted area has a positive relationship and statistically significant at 1% level in determining the yield response of fresh fruit bunch. This finding is valid with the supply response (Nerlove Theory) which stipulates that more planted area enhance the yield of fresh fruit bunch. These results imply that the FFB yield rises by 1.13%, 1.05%, 1.26%, 1.12% and 1.24% for Model 1, Model 2, Model 3, Model 4 and Model 6 respectively, when the mature area of oil palm increase by 1%, holding all other factors constant.

**Table 3:** Estimated long-run coefficients of yield model

Dependent Variable: FFB

Independent Variable	Model 1	Model 2	Model 3	Model 4	Model 6
<b>PFFB</b>	-0.01 (-0.18)	-0.05 (-0.88)	-0.18 (-1.33)	-0.09 (-1.14)	-0.11 (-1.28)
<b>PR</b>	0.06 (0.94)	0.06 (1.23)	-0.02 (-0.22)	0.11 (1.51)	0.09 (1.09)
<b>AREA</b>	1.13 (20.40)***	1.05 (20.23)***	1.26 (11.73)***	1.12 (14.47)***	1.24 (11.81)***
<b>TEMP</b>	-4.13 (-3.10)**		-3.18 (-1.02)	1.38 (0.53)	-0.85 (-0.33)
<b>TEMPS</b>				-3.29 (-1.69)	-4.73 (-1.65)
<b>RF</b>		0.21 (1.39)	1.01 (1.93)*		-3.94 (-1.36)
<b>RFS</b>					2.04 (1.40)
<b>C</b>	6.26 (4.39)**	0.31 (0.53)	1.37 (0.29)	8.02 (1.83)*	14.21 (1.82)*

Note: (\*), (\*\*), and (\*\*\*) denote level of significance at 10%, 5% and 1% respectively.

Model 1 shows an increase of 1% in temperature would reduce about 4.13% of FFB yield at 5% level of significant. It due to high temperature will inhibit the oil palm growth because oil palm metabolism and inflorescences processes were disturbed which usually known as drought stress [18]. The case of water deficit will occur if low rainfall intensity which results in lower FFB yield. Indeed, Model 3 has statistically significant at 10% level suggests that a 1% increase in rainfall will increase the FFB yield by 1.01%. In support of the current results, [12] reported that coefficient of rainfall in linear model was positive and statistically significant. While, this is contrary to Model 2 that shows the impact of rainfall on the FFB yield has not significant.

### 3.3 Coefficient of the Estimated Short-Run Model

The estimated coefficient for the Error Correction Term with one period lag ( $ECT_{-1}$ ) as shown in Table 4 confirms the existence of long-run relationship among the variables in the tested models, since the coefficient has negative sign and was statistically significant at 5%. The  $ECT_{-1}$  value of Model 1 and Model 2 recorded -0.72, and -0.76, respectively, indicate that the speed of adjustment back to equilibrium is 72% and 76% per annum. The  $ECT_{-1}$  is weaker for Model 3, Model 4, and Model 6 taking the range value of -0.45 and -0.46, suggesting that a deviation from the long run equilibrium is corrected with a period lag at the speed of 45% per annum. It should be noted that adjustments in production especially for perennial crop such as oil palm are not instantaneous but usually delayed for two or three production cycles.

**Table 4:** Estimated short-run coefficients of yield model

Dependent Variable: FFB

Independent Variable	Model 1	Model 2	Model 3	Model 4	Model 6
$\Delta\text{FFB}(-1)$					-0.26 (-1.98)*
$\Delta\text{PFFB}$	-0.01 (-0.18)	-0.13 (-3.07)***	-0.06 (-1.50)	-0.04 (-1.16)	-0.05 (-1.41)
$\Delta\text{PFFB}(-1)$		0.10 (2.59)**	0.12 (3.39)***		
$\Delta\text{PR}$	-0.08 (-1.43)	0.04 (1.17)	-0.12 (-2.19)**	-0.01 (-0.31)	-0.05 (-1.07)
$\Delta\text{AREA}$	0.81 (4.71)***	-0.21 (-0.42)	0.57 (3.43)***	0.51 (3.06)***	0.57 (3.20)***
$\Delta\text{TEMP}$	-2.96 (-3.10)***		-2.97 (-3.26)***	0.63 (0.53)	-0.39 (-0.34)
$\Delta\text{TEMPS}$				-3.07 (-3.95)***	-2.17 (-2.42)**
$\Delta\text{R}$		0.16 (1.53)	0.17 (1.57)		-1.81 (-1.75)*
$\Delta\text{R}(-1)$			-0.22 (-2.52)**		
$\Delta\text{RS}$					0.94 (1.83)*
$\text{ECT}_{t-1}$	-0.72 (-4.39)***	-0.76 (-4.54)***	-0.45 (-2.95)***	-0.46 (-3.02)***	-0.46 (-2.73)**
$\text{R}^2$	0.55	0.72	0.84	0.79	0.62
Adjusted $\text{R}^2$	0.45	0.63	0.76	0.73	0.46
DW	1.59	1.95	2.27	1.91	1.86
F-Stat	5.81 (0.00)	8.29 (0.00)	10.17 (0.00)	13.11 (0.00)	3.93 (0.00)
LM	1.18	2.59	2.87	2.92	3.17
HET	8.35	9.78	13.09	6.74	10.12
JB	0.83	0.30	1.18	0.14	0.02
RESET	0.04	0.25	0.94	0.82	1.16

Note: (\*), (\*\*), and (\*\*\*) denote level of significance at 10%, 5% and 1% respectively.

The report showed that the coefficient of yield at lagged two has a negative sign with the value of 0.26 and is significant at the 10% level for Model 6. It signifies that an increase in lagged FFB yield will be followed by a decrease in FFB yield in the next period. The coefficient of price of FFB also shows negative value and significant at 5% level for Model 2, suggesting that the yield reduced by 0.13% when owned price increased by 1%. However, the price coefficient plays an important role in increasing yield of FFB in two period lags that meet a priori expectation and was statistically significant at 5% level for Model 2 and 1% level for Model 3. The estimated coefficient of rubber price was negative and significant at 5% levels for Model 3. In theoretical consideration, land is supposed to be fixed in the short-run analysis in contrast to other inputs like fertilizer, chemical and labor, which undergo short run variations. The partial adjustment of oil palm planted area toward desire level of FFB yield captured by the lagged dependent variable has expected positive sign and significant at 1% level. All models show a 1% increase in mature area of oil palm leads to increase production of FFB by 0.81%, 0.57%, 0.51% and 0.57% for Model 1, Model 3, Model 4, and Model 6, respectively.



Temperature variable is found to impact negatively on the yield of FFB at 1% level with the coefficient value of -2.96 for Model 1 and -2.97 for Model 3. The effect of temperature also reduced the FFB yield for non-linear models, namely Model 4 and Model 6 with the value of -3.07 and -2.17, respectively. In general, the changes in temperature and rainfall negatively affect the selected crops and countries. Table 4 further shows the rainfall coefficient for two period lag has negative sign, and significant at 5% level for linear model (Model 3). The result contrasted to the coefficient value of non-linear model (Model 6) that was negative and significant at 10% level. This indicates that rainfall variable is uniquely explained about the effect to FFB yield. Of the two climate change scenarios considered in this study, the high temperature scenario is more extreme due to the high magnitude which caused a drought condition and harmful for the growth of oil palm in short-run consideration.

Diagnostic tests for serial correlation, functional form, parameter stability, normality and heteroscedasticity were conducted and the results are shown in Table 4. These results show that null hypotheses could not be rejected at 5% level of significant, which imply that there no suspicious of multicollinearity among variables as functional form of the model is well specified and there is no evidence for heteroscedasticity as well. Besides that, the plots of CUSUM and CUSUMSQ statistic fall inside the critical band of the 5% confidence interval of parameter stability for all tested models.

#### 4. Conclusions

Overall, Model 3 has been chosen as the best model to postulate the yield response of linear model, while Model 6 to represent the non-linear model when the short-run and long-run effects were considered. Both models were selected because most of the independent variables the models have the expected sign and statistically significant. While, Model 5 was not included because detected no co-integration through Bound test co-integration. The results showed planted area has a positive relationship with the FFB yield for all models. Among the climate variables, the coefficient of temperature was statistically significant with negative values for both short-run and long-run consideration. While, the estimated coefficient of rainfall variable has negative effect in two periods lagged for the short-run basis, but have a positive effect on the long-run consideration. According to the results, as far as climate-related effects are concerned, the FFB yield is most adversely affected by a rise in temperature in comparison to an increase in rainfall. This study contributes to identifying the magnitude effect of climate change using different approaches and as a basis for the analysis of projected oil palm yields in Malaysia. Therefore, the results can help oil palm stakeholders' deal with drought and flood events.

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