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CLIMATE CHANGE AND RICE PRODUCTION: EMPIRICAL INVESTIGATION FROM MALAYSIA

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Abstract:

This paper investigates the link between CO_2 emissions, average temperature, planted area, fertiliser use, and rice productivity in Malaysia., covering the period from 1980 to 2018. For this purpose, the study employs the Autoregressive Distributed Lag (ARDL) bounds testing approach and Error Correction Model (ECM) to examine the short-run and long-run relationship among the selected variables of this study. The empirical results obtained from the analysis suggest that carbon dioxide (CO_2) emissions and temperature have a long-term favourable influence on rice output in Malaysia but a short-term detrimental impact. Finally, the results obtained from several diagnostic and stability tests are robust, stable, and reliable. The finding of this study could be highly significant for adequate policymaking to reduce the impact of climate change in Malaysia.

Keywords:

Rice Production, CO_2 Emission, Temperature, ARDL, Cointegration, Short And Long Run

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Introduction

Malaysia, being a developing country, faces tremendous challenges in its agriculture business. The agriculture sector's contribution to the country's gross domestic product (GDP) fell from 43.7 percent in 1960 to 8.02 percent in 2017. This appears to be contradictory given the country's agricultural land increase from 9.4 percent in 1961 to 26.3 percent of total land area in 2015 (World Bank 2021). Rice is a staple meal for the majority of the world's population, and it is consumed by around 3 billion people (Fukagawa et al., 2019; Krishnan et al. 2011; Yu et al. 2012). Approximately 90% of the world's rice is produced and consumed in Asia (Wassmann et al. 2009). Rice is Malaysia's second most important food crop, behind wheat. It is critical to the country's agricultural economy. Despite its tiny contribution to the nation's GDP, the paddy and rice business has piqued the interest of policymakers due to its complicated link with food security, culture, and socioeconomic concerns. This is prompted by the rising national demand for rice (Figure 1), which is the result of a steady harvest area size. In reality, there is a growing disparity between Malaysia's rice output and consumption (Figure 2).

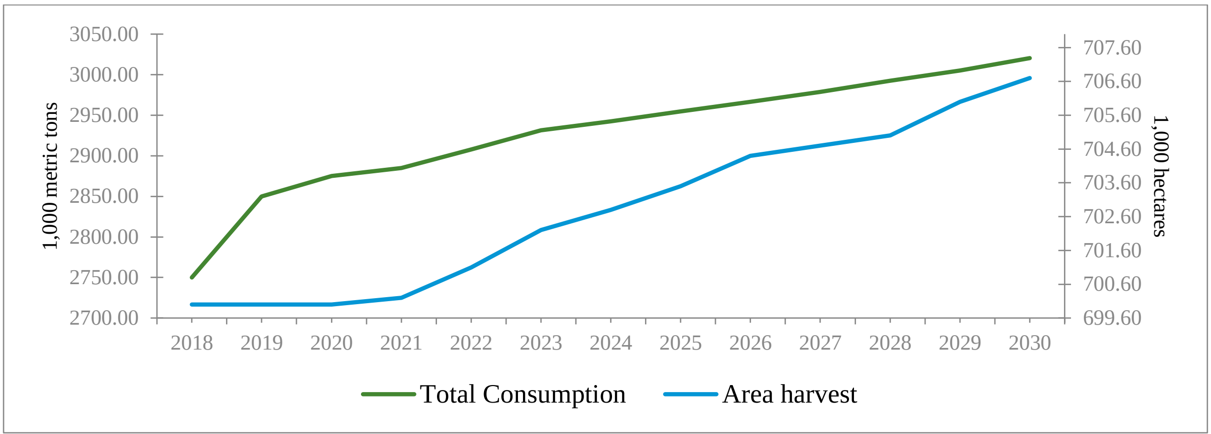

Figure 1: Projected Total Rice Consumption and Area Harvested of Rice in Malaysia during 2018-2030

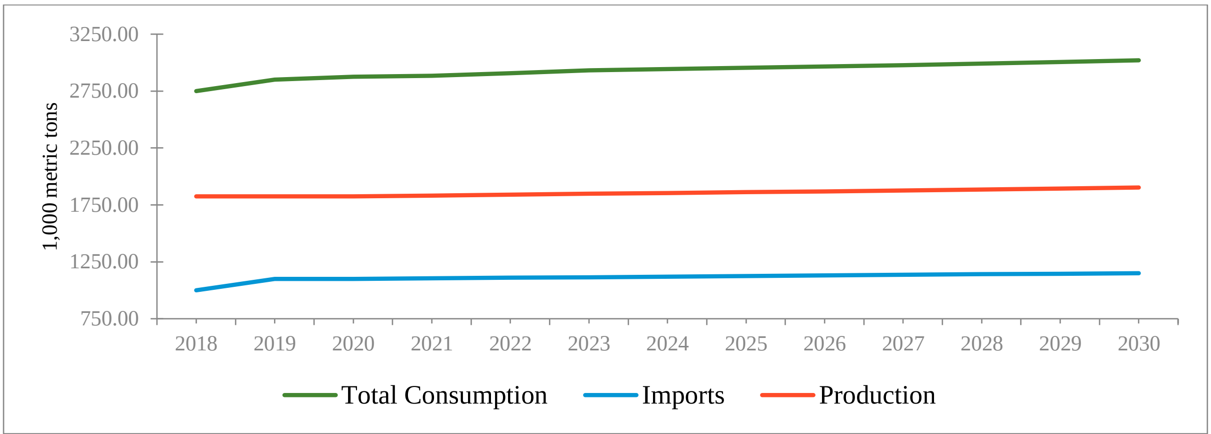

Figure 2: Projected Total Consumption, Imports and production of Rice in Malaysia during 2018-2030

Agriculture is an important component of Malaysia's economy, producing 12 percent of national GDP, employing 16 percent of the total population, and improving living in rural areas via a variety of activities (Mannan et al., 2017). Many studies in Malaysia have investigated

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the impact of climate change on crop production and found that climate change has a negative impact on the agricultural sector (Tang, 2019; Alam et al., 2012; Ali et al., 2017; Herath et al., 2020; Masud et al., 2014; Siwar et al., 2009; Vaghefi et al., 2011). Climate change, according to Tang (2019), climate change has had an influence on Malaysia's agriculture industry due to rising temperatures and uncertain rainfall variability year after year. Extreme weather conditions, such as floods or drought, can impact agricultural crops like rice (Akhtar et al., 2019; Alam et al., 2011). For example, Masud et al. (2017) and Herath et al. (2020) used average temperature and rainfall to analyse the influence of climate change on rice output in Malaysia. They observed that temperature and rainfall both had a detrimental influence on paddy yield. Only a few studies have combined climate change and economic considerations to explain rice production. Agricultural production, such as rice production, is, nonetheless, distinct from manufacturing output. Climate change variables (CO_2 emission and temperature) and economic variables should not be utilised to explain rice production. As a result, the purpose of this study is to investigate the influence of climate change and economic variables on Malaysian rice production.

Econometric Methodology

Data

For this empirical investigation, we used a number of relevant factors. The dependent variable is rice production, and the independent variables include carbon dioxide emissions (CO2), and average temperature. This study also took into account additional economic factors such as rice crop acreage and fertiliser use. Annual time series data for rice production, rice crop area, and fertiliser usage from 1980 to 2018 are derived from various sources (see Table 2). A realistic approach for empirical estimation is required to explore the effects of climate change on rice production. This study employed many econometric techniques, including (i) the ADF, PP, and KPSS unit root tests, (ii) the ARDL limits testing approach for cointegration and (iii) the model's parameters stability test using CUSUM and CUSUM square.

Table 2: Description of Data

Abbreviation	Variable name	Unit of measurement	Source
RP	Rice Production	Thousand tons	Department of Statistics Malaysia: https://www.dosm. gov.my/.
CO_2	Emission of Carbon dioxide	Thousand metric tons	World Development Indicators (WDI): https://databank.worldbank.org/source/world
T	Average temperature	Celsius degree centigrade	World Development Indicators (WDI): https://databank.worldbank.org/source/world
A	Area under rice crop	Thousand hectares	Department of Statistics Malaysia: https://www.dosm. gov.my/.
F	Fertilizer Consumption	Thousand nutrient tons	Department of Statistics Malaysia: https://www.dosm. gov.my/.

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The Autoregressive Distributed Lag Approach

The study applies the ARDL cointegration method is used to test the long-term connection between income inequality and CO2 emissions. The model was introduced by Pesaran et al. (2001) and is used to test cointegration between specific variables in the long run (Islam et al., 2012). Fortunately, the introduction of the ARDL approach has warded off the problem of stationarity. With ARDL, one can test for cointegration without having stationarity. In other words, the ARDL does not require the series to be integrated of order zero I (0); it can be applied to both I (0) and I (1) or a mixture of I (0) and I (1) series. Hence, The ARDL approach limits the concerns caused by unit root tests (Hundie, 2014, 2018; Jalil & Mahmud, 2009; Wolde-Rufael & Idowu, 2017). It is worth mentioning that the ARDL model is not giving accurate results for I (2) series Narayan (2004). Another advantage of the ARDL approach compared to other approaches is that it can be employed for a small sample size. (Hundie, 2014; Jalil & Mahmud, 2009; Menyah & Wolde-rufael, 2010; Pesaran et al., 2001; Wolde-rufael & Idowu, 2017). Moreover, the ARDL approach estimates relationships for both short and long-run simultaneously (Hundie, 2014; Jalil & Mahmud, 2009; Wolde-rufael & Idowu, 2017). The ARDL model is helpful because it corrects the endogeneity of the independent variables (Menyah & Wolde-rufael, 2010; Panopoulou & Pittis, 2004). The unrestricted error correction model (UECM) of the ARDL approach for Eq. 3.5 is as follows:

$$\begin{aligned}\Delta LNRP_t = \ & \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta LNRP_{t-i} + \sum_{i=0}^{q_1} \eta_{1i} \Delta CO_{2_{t-i}} + \sum_{i=0}^{q_2} \gamma_{1i} \Delta LNT_{t-i} + \sum_{i=0}^{q_4} \mu_{1i} \Delta LNA_{t-i} \\ & + \sum_{i=0}^{q_5} \phi_{1i} \Delta LNF_{t-i} + \delta_1 LNRP_{t-i} + \delta_2 LNCO_{2_{t-i}} + \delta_3 LNT_{t-1} + \delta_4 LNA_{t-1} \\ & + \delta_5 LNF_{t-1} + \varepsilon_t \ldots\ldots\ldots (1)\end{aligned}$$

Equation (1) above represents the difference, the Schwarz Bayesian criterion (SBC) suggests a maximum order of 2 for lag length in this ARDL approach. (Pesaran & Shin, 1999), believe that considering the Schwarz Bayesian criterion (SBC), employing two lags is more appropriate in the ARDL approach. Besides, the $\beta_i, \eta_i, \gamma_i, \theta_i, \mu_i, \phi_i$, are the dynamic coefficient in short-run and δ_i $(i = 1,2,3, \ldots, 5)$ represents the long-run relationship among series in the ARLD approach. To test the long relationship among the variables, the first is to employ the F-test for the above equation (1). The test is used to investigate the null hypothesis (H_0), which supports no connection of variables in the long run (Shahbaz & Amir, 2008). The null and alternative hypotheses can also be summarized as below:

$$Null\ Hypothesis: H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$$

$$Alternative\ Hypothesis: H_a: At\ least\ one\ of\ the\ multiplier\ (\delta\ ) is\ differnt\ from\ zero$$

The existence of long-run connection among the series is tested by comparing the value of F-statistics with two critical values, which are also called the lower and upper bounds Pesaran et al. (2001). The first collection of critical values, also known as lower bound, concludes the I (0) series. In contrast, the second one, known as the upper bound, represents variables integrated of order one I (1) in the ARDL model. The null hypothesis can be rejected, with a greater value of the F-test than the upper bound. Meanwhile, if the value is less than the lower

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bound, one cannot reject the null hypothesis stating any connection among variables in the long run. If the value of F-statistics was between the two bounds. In that case, the findings are called to be inclusive, and, in such cases, an alternative co-integration method should be employed (Uzar & Eyuboglu, 2019). Because the F-test is more sensitive to the lags order selection Shahbaz et al. (2015), we employ Schwartz Bayesian Criterion (SBC) instead of Akaike information (AIC) criterion to choose the proper lag length. This is mainly because AIC chooses the maximum number of lags, while SBC selects the lowest one Saboori and Soleymani (2011).

After testing for the co-integration, we employ the Error Correction Model to look for the short-run connection between the variables. The model introduced by (Sargan, 1974) is designed for describing the short-run dynamics in ARDL. The model is specified as below:

$\Delta LNRP_t = \alpha_2 + + \lambda ECT_{t-i} + \varepsilon_{2t}$ ………… (2)

In the equation 2, λ indicates the speed of adjustment and ECT_{t-i} Which stands for the error correction term and represents the residuals obtained from the previous equation of co-integration. Moreover, the ε_{2t} stands for the error in the model. The error term or ε_{2t} is assumed to be identically independent and distributed normally. The speed of adjustment (λ) shows how quickly the variables return to the long-run equilibrium.

Empirical Findings and Discussion Descriptive Statistic

Table 3 shows the descriptive statistics of the variables that were used in this study. Based on the results of Jarque-Bera statistics, all variables are found to be distributed normally and they have constant variance and zero covariance.

Table 3: Descriptive Statistics for Study Variables

	A	CO_2	F	L	RP	T
Mean	676075.6	152.9090	1383.504	1770.744	2147980.	25.61538
Median	677884.0	159.1841	1267.795	1850.000	2127271.	25.62000
Maximum	716800.0	257.6483	2491.688	2049.000	2741404.	26.30000
Minimum	614579.0	39.16400	387.0225	1344.000	1571674.	24.96000
Std. Dev.	20214.27	77.06562	597.1323	207.6594	323907.9	0.270884
Skewness	-0.897662	-0.088858	0.095502	-0.615843	0.142962	0.060391
Kurtosis	4.661694	1.527715	1.867465	2.095933	2.096329	3.334105
Jarque-Bera	9.724673	3.573708	2.143569	3.793383	1.459858	0.205098
Probability	0.007732	0.167486	0.342397	0.150064	0.481943	0.902534
Sum	26366948	5963.450	53956.66	69059.00	83771231	999.0000
Sum Sq. Dev.	1.55E+10	225686.2	13549545	1638651.	3.99E+12	2.788369
Observations	39	39	39	39	39	39

Likewise, Table 4 reports the correlation matrix which reveals that there is a closest positive correlation between carbon dioxide (CO_2) and rice production followed by fertilizer consumption, average temperature and area harvested.

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Table 4: Correlation Matrix

	LNRP	LNA	$LNCO_2$	LNF	LNT
LNRP	1				
LNA	0.438148	1			
LNCO2	0.798507	0.013521	1		
LNF	0.685932	-0.09085	0.943762	1	
LNT	0.610382	0.19076	0.704501	0.634768	1

Unit Root Tests

This study tested the stationarity of the variables by applying the ADF test, the PP and the KPSS unit root tests. The results of unit root tests in Table 5 show that emissions of carbon dioxide ($lnCO_2$), average temperature (lnT) and area under rice crop (lnA) are stationary at levels I(0) whereas rice production (lnRP) and fertilizer consumption (lnF) are integrated of the first order I(1) with intercept. Therefore, an ARDL approach to cointegration can be applied to inspect the influence of climate change and other variables on rice production in Malaysia over the period of 1980–2018.

Table 5: Unit Root Test

Variables	ADF test statistics	PP Test Statistics	KPSS test statistics
At level			
LNRP	-1.84	-1.48	0.66
LNA	-4.33	-4.3	0.06
LNCO2	-3.31	-2.78	0.72
LNF	-1.9	-2.05	0.71
LNT	-3.32	7.26	0.7
First difference			
LNRP	-6.33	-10.09	0.17
LNA	-8.23	-8.46	0.13
LNCO2	-5.79	-5.89	0.5
LNF	-4.08	-8.11	0.25
LNT	-7.26	-23.21	0.28

Table 6 reports the ARDL bound testing approach. The results shown in Table 7 reveal that the F-Statistics is 5.63 which exceeds the upper bound limit at 10, 1, and 5% levels of significance. This result implies that there is long run relationship among the variables when rice production (lnRP) is used as dependent variable. In addition, the estimated outcomes of various diagnostic tests in Table 7 reveal that error terms of all the specifications of the ARDL bounds test for cointegration models are normally distributed and the residuals free from heteroscedasticity and serial correlation.

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Table 6: The ARDL Bounds Test for Cointegration

Critical Value	Lower Bound	Upper bound
1%	3.81	4.92
5%	3.05	3.97
10%	2.68	3.53
$LnRP/(LnA, LnCO_2, LnF, LnT)$	F – statistics	Co- integration
	5.63	Yes

Table 7: Diagnostic Tests of the Model

Tests	F-Statistic	P value
x^2 Serial	0.6321	0.1834
x^2 Normal	0.3752	0.8289
x^2 Arch	0.8840	0.8795
x^2RESET	0.8833	0.3771
CUSUM	Stable	
CUSUM Square	Stable	

Long-Run and Short-Run Estimations

Table 8 shows the long-run impacts of carbon dioxide (CO_2) emissions, average temperature, harvested area, and fertiliser consumption on rice production in Malaysia. The results in Table 8 show that carbon dioxide (CO_2) emissions in Malaysia have a positive and significant impact on rice production. The long-run coefficient of CO_2 emissions demonstrates that, at a 5% level of significance, a 1% rise in CO_2 emissions results in a 0.17 percent increase in rice production in Malaysia. This result is consistent with Janjua et al., (2014) who also found that CO_2 has positive impact on rice production. Rice plants develop more quickly when there is an increase in atmospheric CO2, and this increased plant growth gives soil microbes more energy, which speeds up their metabolism. The yield of rice will similarly increase when CO2 levels rise, but to a lesser proportion (Van et al., 2013). However, as CO2 levels rise, the atmosphere has the ability to absorb more heat, which is unfavorable for the growth of rice. Because of this, the short-term effects of CO2 emissions on rice output in Malaysia are negative. According to the coefficient of short-run CO2 emissions, a 1% increase in CO2 emissions causes a 0.19 percent decrease in rice yield. Amponsah et al. (2015) also observed the negative impact of CO_2 emissions on cereal crops production in both long-run and short-run in Ghana. Janjua et al. (2014) explored that climate change factors including CO_2 emissions, average temperature, and average precipitation have positive influence on wheat productivity in both long-run and short-run in Pakistan.

Table 8: Results of Long-Run and Short-Run Coefficients Employing the ARDL Method

Dependent variable is lnRP: ARDL (1, 0, 0, 1, 0) selected based on AIC				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Long run				
LNF	-0.117***	0.067	-1.757	0.011
$LNCO_2$	0.171**	0.093	1.843	0.057
LNA	2.127***	0.509	4.183	0.000
LNT	-7.855**	2.451	-3.205	0.004
Short Run				

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D(LNF)	2.322***	0.787	2.951	0.007
D(LNCO2)	-0.186	0.108	-1.726	0.097
D(LNA)	2.917***	0.216	13.511	0.000
D(LNT)	-2.626***	0.707	-3.712	0.001
ECM	0.699***	0.110	6.368	0.000
R-squared	0.823675			
Adjusted R-squared	0.802302			
F-statistic	42.71422***			

*** and ** denote the significant levels at 1% and 5%, respectively

Furthermore, at a 5% level of significance, it is found that rice production is favourably impacted by area under cultivation in the long and short run. A 1% increase in cultivation area is predicted to result in a 2.13% and 2.92% rise in rice production in the long run and short run respectively. This finding is compatible with (Chandio et al. 2020; Hussain, 2012). Fertilizer intake has been shown to have a detrimental influence on rice production at a 1% significance level in the long run. The coefficient of fertilizer shows that a 1% increase in fertiliser usage is predicted to reduce rice production by 0.12%. Surprisingly, in the short run the coefficient of fertilizer usage is positive which reveals that at 1% level of significance, if fertilizer usage is increased by 1%, rice production will be increased by 2.32% in Malaysia. This study's findings corroborate those of Chandio et al. (2020), Hussain (2012), and Janjua et al (2014). Fertilizers greatly influence crop productivity by enhancing plant growth and improving the fertility of the soil. In the long run, excessive fertilizer use would lower the fertility of the available land, which would lower crop output. To increase the fertility of the land, the majority of farmers in Malaysia's rural areas employ both chemical and natural fertilizers. Chemical fertilizers in the recommended dose are crucial in helping Malaysia produce more rice. In 2018, fertilizer consumption for Malaysia was 2,106.5 kilograms per hectare. Fertilizer consumption of Malaysia increased from 175.1 kilograms per hectare in 1969 to 2,106.5 kilograms per hectare in 2018 growing at an average annual rate of 6.82% (knoema, 2019).

However, the coefficients of temperature exhibit a negative impact on rice production both in long run and short run. This reveals that a 1% increase in temperature reduces rice production by 7.86% and 2.63% in the long run and short run respective. Furthermore, at the 1% level of significance, the coefficient of ECM is -0.6999. This indicates that adjustment occurs at a rate of 0.70 percent per year toward the long-run equilibrium. R^2 and adjusted R^2 were calculated to be 0.80 and 0.82 percent, respectively which argues that our model is well-fitted. In addition, the results shown in Table 8 prove that the estimated ARDL model has passed all diagnostic tests. Moreover, the ARDL model has also passed the stability tests, as evidenced by the graphs of recursive residuals (Figure 3 and 4).

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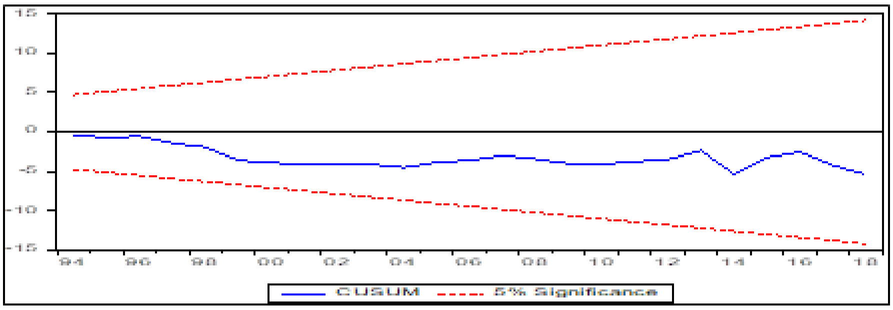

Figure 3. Plot of CUSUM Test

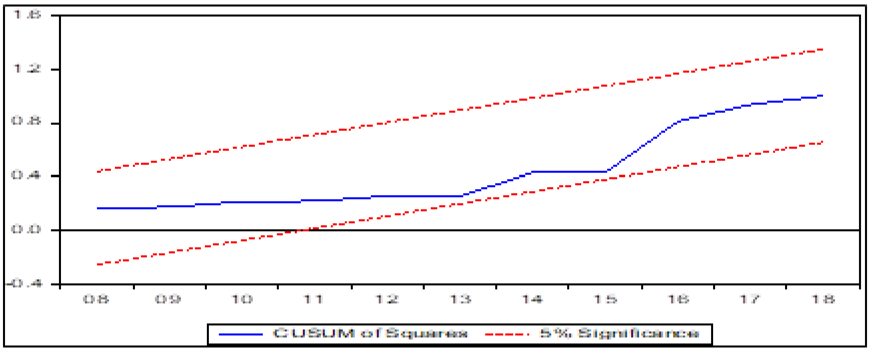

Figure 4. Plot of CUSUM of Squares Test

Concluding Remarks

This paper investigates the impacts of climate change on rice production in Malaysia, by using annual time series data from 1980 to 2018. The estimated outcomes show the evidence of cointegration and long-run interrelationship between climate change factors including carbon dioxide (CO_2) emissions and average temperature and with other variables such as area under rice crop, usage of fertilizers, and the rice production in Malaysia. Furthermore, results of the ARDL shows that CO_2 emissions and the average temperature have a positive impact on the output of rice crop in Malaysia in the long-run but they have negative impact in the short-run. Likewise, the area under cultivation has a positive influence on the rice production, both in long-run and short-run, whereas the usage of fertilizer also has a positive influence on the rice production in the long-run, but it has a negative influence on the output of rice production in the short-run.

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