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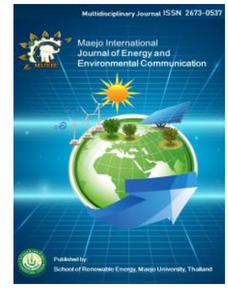

ARTICLE

Estimating the potential effects of climate change on GDP in the agriculture sector by countries in the ASEAN region

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ABSTRACT

This study estimates the potential effects of climate change on GDP in the agriculture sector in the ASEAN region based on historic data from 1995-2018. An econometric panel model is applied to examine the impact of the changing climatic and non-climate variables AGDP. The empirical estimation results show that some significant and insignificant. Based on estimation results, if the policymaker is concerned about climate change actions, it helps more comprehensive risk decision-making, and policy exertions should be concentrated toward climate change to the total gross domestic product in the ASEAN region. Under projections of the future climate change, the simulation results reveal that the substantial change in GDP in agriculture in the ASEAN region arises due to the fluctuation of temperature and precipitation. For instance, GDP in the agriculture sector would be decreased by 0.27% to 0.90% in response to different scenarios over the century. Therefore, it is necessary to take immediate adaptive actions appropriately to mitigate the decrease in GDP in the agriculture sector in the ASEAN region.

1. Introduction

The cumulative effects of global climate change depend on how the world responds to increasing emissions (Bhuyar et al., 2019; Saengsawang et al., 2020). The evidence indicates that climate change has already resulted in extreme weather events and sea level rises (SLRs), with added threats to agricultural production in many parts of the world (Figueres, 2019). Indeed, there have been relatively few attempts to examine the entire global, disaggregated, and intertemporal effects of climate change on GDP using large-scale economic modelling, modelling that would capture all of the trading patterns, spillover effects, and economic linkages among countries in the global economic system over time. To date, given its computational complexity, computable general equilibrium (CGE) modelling has primarily concentrated on individual country effects or dynamic models with limited numbers of countries or regions and an absence of forward-looking behaviour, that is, so-called recursive dynamic models with static or adaptive price-level forecasts. These recursive dynamic models have value, but the assumption that future price-level expectations

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are based only on current and past values is broadly incongruent with known future projections of various climate change outcomes and resulting trade effects (Kompas and Van Ha, 2019).

Climate change is mainly attributed to the unabated increase in greenhouse gases, including fluorinated gases, carbon dioxide, methane, and nitrous oxide, which cause changes in rain patterns, temperature, and adverse effects on water and land resources, including floods and droughts. Climate change is considered to be a global phenomenon. However, its impacts are more widely felt in developing countries due to their more significant vulnerabilities and less able to mitigate climate change (DehghanSh et al., 2017). Natural systems, human health, and agricultural production have been badly affected by devastating environmental change (Arunanondchai et al., 2018). With the rapid increase in the world's population, there is a corresponding increase in food demand due to concerns about the stability of the global environment. Water availability, air pollution, and soil fertility significantly impact agriculture productivity (Noya et al., 2018). The emission of dangerous gases, especially CO_2, is the main factor for the greenhouse effect and warmer average global temperature (Raza et al., 2019). The effects of climate change and environmental variation are mainly estimated by the number of stress spells, their impact on daily life, and damage to agriculture crops (UNICEF and Organization, 2017).

In developing countries, agricultural yields predominantly suffer due to adverse environmental conditions. Therefore, high temperatures and excess CO_2 accumulation force scientists to devise new strategies to cope with less predictable challenges (Rosenzweig et al., 2014). Eco-physiological stresses greatly influence plant growth and yield. Under natural climate conditions, plants often experience numerous stresses like waterlogging, drought, heat, cold, and salinity (Ashraf et al., 2018). All living organisms, such as plants, animals, fishes, and humans, have been affected by extreme environmental conditions around the globe. The danger of the world's climate conditions has triggered anxiety because crop yields might be compromised by fluctuations in various environmental factors that can risk food security. Recent studies have reported that developed countries are more vulnerable to climatic change (8-11%) than developing countries (Altieri and Nicholls, 2017).

The study's primary objectives are to measure the potential impacts of climate change on GDP in the agriculture sector in the ASEAN region and to suggest policy and prescription based on the finding of this study. To present a modelling framework to create scenarios of climate change effects on GDP in the agriculture sector in the ASEAN countries in the future that can be used as an input in integrated assessment modelling and other climate research applications that require GDP projections in the very long run. Specifically, we constructed historical temperature and precipitation data for each country and year in ASEAN from 1995 to 2018 and combined this dataset with historical growth data. The primary identification strategy uses year-to-year fluctuations in temperature and precipitation within countries to estimate the potential impacts of climate and non-climate variables on GDP in the agriculture sector in the ASEAN region.

2. Materials and Methods

This research was directed in different countries of the ASEAN region. The information that is relevant to the research on "The potential impacts of climate and non-climate variables on GDP in agriculture in the ASEAN region is quantitative research which uses secondary analysis data in spatial form, time series and cross-section data to analyze each region which statistics are used in the form of annual countries, established by research from 1995-2018”. This section presents the econometrics panel data analysis regression model and theoretical arguments that justify the nine variables used. The regression model was formulated as follows:

$$AGDP_{it} = \mu + \beta_1 lnpre_{it} + \beta_2 lnvarpre_{it} + \beta_3 lnavtem_{it} + \beta_4 lnvartem_{it} + \beta_5 lnlf_{it} + \beta_6 cab_{it} + \beta_7 inf_{it} + \beta_8 tinv_{it} + \beta_9 T_{it} + u_{it}$$

Where:
$AGDP_{it}$ = GDP in the agriculture sector, in USD$ in the ASEAN region.
$lnpre_{it}$= Total precipitation in millimetres
$lnvarpre_{it}$= Variance precipitation in millimetres
$lnavtem_{it}$= Average temperature in Celsius
$lnvartem_{it}$= Variance temperature in Celsius
$lnlf_{it}$= Labor force in people
cab_{it}= Current account balance in percent change
inf_{it}= Inflation rate (average consumer price)
$tinv_{it}$= Total investment in percent change
T_{it}= Time trend, i stands for 10 countries in the ASEAN region, t stands for the year
u_{it} is the error term for the fixed effects model.

2.1. Data

For estimating the potential effects of climate change on GDP in the agriculture sector by countries in ASEAN, secondary data was castoff. Data on GDP in the agriculture sector was acquired from World Bank Statistics of the ASEAN region, whereas data on temperature and precipitation were obtained from Regional Meteorological Center (RMC) in each ASEAN countries Meteorological Department. This section allows the visualization of climate variables and indices derived from scientifically vetted CMIP5 projections for different timeframes, statistics, emission scenarios, and climate models. Metadata: future climate information is derived from 35 available global circulation models (GCMs) used by the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report.

2.2. Measurement and definition of variables used in model

- Dependent variable: GDP in agriculture sector, in USD$ in the ASEAN region.
- Independent variable: Independent variables were categorized into two parts, climatic variables and non-climatic variables.

- Climatic variable: Climatic variable exemplifies total precipitation, variance precipitation, average temperature, variance temperature.
- Non-climatic variables: Labor-force, Current account balance, Inflation rate, Total investment.

2.3. Description of data

The data used in this study contain GDP in the agriculture sector in the ASEAN region and climate data. GDP in agriculture sector data is from 7 countries, including Cambodia, Lao PDR, Myanmar, Vietnam, Thailand, Malaysia and, the Philippines. Over the period from 1995-2018. The GDP in agriculture sector data is retrieved from (world bank open data).

Data of climatic conditions are derived from the Regional Meteorological Center (RMC) in each ASEAN countries Meteorological Department. Specifically, monthly temperature and precipitation measurements at the country level are collected from a representative weather station located in the centre of each country. The descriptive statistic across all the data used are presented in Table 1. As can be seen, the precipitation resulted in a mean of 2,333.14 mm with a standard deviation of 568.77 mm. The minimum and maximum total precipitation in the research area were 1,530.37 mm and 3,179.85 mm, respectively. The calculated mean of variance-precipitation noted is 11,019.83 mm with a maximum value of 28,403.44 mm, and the minimum is 2,580.82 mm, whereas the standard deviation premeditated is 8,341.07 mm. The mean average temperature is 27.18°C with a minimum and maximum of 23.70°C and 29.70°C respectively, while the standard deviation is 1.11°C. The mean-variance temperature calculated is 12.32°C with a standard deviation of 8.91°C, while the minimum and maximum are 0.53°C and 28.11°C correspondingly.

Table 1 Descriptive statistic of variables used for panel data (1995-2018).

Variables	Mean	Std.Dev.	Min	Max
AGDP (M USD$)	13,800	11,100	434	47,600
Total-precip (mm)	2,333.14	599.54	1,530.37	3,179.85
Var-precip (mm)	11,019.83	8,341.07	2,580.82	28,403.44
Avg-temp (°C)	27.18	1.11	23.70	29.70
Var-temp (°C)	12.32	8.91	0.53	28.11
CAB (%)	(0.31)	6.56	(15.76)	16.86
Labor force (ppl)	23,580,120	16,270,089	2,180,639	56,915,235
Inflation rate (%)	7.99	14.59	(4.28)	125.27
Total investment (%)	4.24	2.93	0.06	14.15

Source: world bank group

3. Empirical Results

3.1. Pre-estimation specification test

Before estimating the GDP in the agriculture sector, three specification tests, including unit root test, heteroscedasticity test, and fixed and random effects test, are performed. We use the panel unit root test with both the (Westerlund and Breitung, 2013) methods adopted to examine whether the variable is stationary and find that they are (see Table 2). Hence, no corrective differential procedures are needed. The heteroscedasticity test (Breusch-Pagan-Godfrey and White) firmly rejects homoscedasticity's null hypothesis at all conventional significance levels. To deal with common panel data problems (such as autocorrelation or cross-correlation in cross-sectional units at the same point in time), we run the fixed effects model and random-effects model, which better estimate the pooled OLS. As a statistical tool for determining whether a fixed or random-effects model is a plausible fit for data, the Hausman test is used, and its result indicates that the fixed effects model is more appropriate (Table 3)

Regression analysis with panel data in case of variance problem. Inaccurate (Heteroscedasticity), it is necessary to test the suitability of the data first. To obtain effective analysis results in a regression analysis model, research and testing are required. The stability of the panel data (unit root) of each variable before regression analysis. To avoid spurious correlation, perform a stability test of balance panel data using 2 methods. 1) Levin, Lin and Chu (LLC) (Levin et al., 2002), and 2) Im, Pesaran and Shin (PIS) (Im et al., 2003). The tests revealed that the GDP in the agriculture sector in the ASEAN region, total precipitation, variance-precipitation, average-temperature, variance-temperature, current account balance, labour force, inflation rate, and total investment are all stationary. Hence, it is not necessary to determine the difference between the data before performing the regression analysis. In addition, we have also tested the problem of the variance of inconstant error.

Table 2 Unit root test of variables used for panel data analysis (1995-2018).

Variables	LLC Test	IPS Test
$AGDP$ (M US$)	-3.885***	-3.263**
Total-Precip (mm)	-6.075***	-8.879***
Var- Precip (mm)	-1.848**	-1.94**
Avg-temp (°C)	-7.427***	-6.716***
Var-temp (°C)	-3.491***	-4.706***
CAB (%)	-4.689***	-5.809***
Labor Force (ppl)	-3.134***	-0.038
Inflation rate (%)	-1.825**	-3.850***
Total investment (%)	-1.351*	-2.256**
Heteroskedasticity Brush-Pagan-Godfrey Test		6.588***
Heteroskedasticity ARCH Test		79.304***

Source: World bank group
*, ** and *** indicate that the null hypothesis of nonstationary is rejected at the 1, 5 and 10% significance level.

To find the relationship, the variance describes the error in the form of experiments of the long-term variables and the error in the climate change model with gross countries' product in the agricultural sector employing The Breusch-Pagan-Godfrey test to determine. Relationship between the square error and the explanatory variable and the autoregressive method. Conditional Heteroscedasticity (ARCH) was determined by determining the relative square of values error with the lag from the test results of both methods, and it was discovered that the variance of the error was not constant. Hence, the general regression analysis feasible (FGLS) is appropriate for analyzing climate change with GDP in the agriculture sectors, as shown in Table 2.

Table 3 Specification test results for the panel model

Heteroscedasticity	The ASEAN region
B-P-G test	4.574***
White test	1.529**
Fixed versus random effects test[s]	56.28***

The statistic of the B-P-G test and White's test are F-statistic.
[b] The fixed versus random effects test is performed Hausman test with the Chi-square statistic.
*The null hypothesis is rejected at 1% of significance.

3.2. Estimate of GDP in the agriculture sector in the ASEAN region

The FGLS procedure is used to estimate the parameters. The estimation results of the fixed effect model from panel data are illustrated in Table 3. For the gross domestic product in the agriculture sector in the ASEAN region, the effects of time trend (T) on the GDP in agriculture in the ASEAN region are all positive and statistically significant at a 99% confidence level. This indicates that technological progress was significant during the sample period. Precipitation revealed a significant positive effect on GDP in the agriculture sector, which means a 1% increase in total precipitation boosted GDP in agriculture by 0.001 %. The findings also confirmed that the agricultural sector's variance-precipitation contribution to AGDP is negative significant at a 90% confidence level, a 1% increase of variance precipitation decrease 0.0005% in GDP. For the impact of climate change on GDP in agriculture, the overall effect of temperature is significant and negative in most GDP in agriculture in the ASEAN region. Specifically, an increase in average temperature reduced GDP in the agriculture sector in the ASEAN region; for instance, a 1% in average temperature increase leads to GDP in the agriculture sector in the ASEAN region declines by 0.066%. The variability in temperature is insignificant.

The effect of non-climate variables as the labour force shows a negative impact and is statistically significant at a 99% confidence level, where a 1% increase in the labour force induces a decrease in GDP in the agriculture sector in the ASEAN region 0.717%. The results also show that an increase in the current account balance could decrease GDP in the agriculture sector by 0.0119%. The fallout further declared the inflation rate statistically significant at a 99% confidence level but negative. For instance, a 1% inflation rate increase leads to GDP in the agriculture sector in the ASEAN region declining by 0.717%. Furthermore, the agriculture sector's total investment in percent change shows a positive and statistically significant at 99% confidence level contribution to GDP in the agriculture sector in the ASEAN region, a 1% increase in total investment in percent change boost GDP in the agriculture sector in the ASEAN region by 0.020%. Estimating the potential impacts of climate and non-climate variables in GDP in the agriculture sector in the ASEAN region show some significant and insignificant variations in climate change and non-climate change variables with the GDP in the agriculture sector in the ASEAN region. The overall effects of climate in precipitation on GDP in the agriculture sector in variability are adverse. Higher total precipitation on GDP in the agriculture sector in the ASEAN region is positive for most AGDP in the ASEAN region. The independent variable related to average temperature is the negative impact on GDP in the agriculture sector in the ASEAN region.

Table 4 Estimation from climate change model to the GDP in the agriculture sector.

Variables	Panel Least Square	LOG Panel Least Square	LOG FGLS
Constant	3.420069	36.91218***	35.23172***
	(1.112351)	(4.754645)	(1.782400)
LNPRE	0.009749***	-0.002223**	0.001168**
	(0.000716)	(0.001047)	(0.000476)
LNVARPRE	-0.003738***	2.888805	-0.000592*
	(0.000677)	(0.000686)	(0.000315)
LNAVTEM	0.064284**	-0.111587**	-0.066685**
	(0.027552)	(0.045371)	(0.029103)
LNVARTEM	-0.009805***	0.000544	0.001732
	(0.003629)	(0.002890)	(0.001464)
LNLF	0.997918***	-0.748727***	- 0.717032***
	(0.032348)	(0.280557)	(0.096863)
CAB	-0.001284	-0.013547***	-0.011974***
	(0.004996)	(0.003790)	(0.001587)
INF	-0.001162	-0.000625	-0.717032***
	(0.001852)	(0.001372)	(0.096863)
TINV	-0.003038	0.028302***	0.020712***
	(0.009941)	(0.008943)	(0.003594)
T-trend	0.044873***	0.086425***	0.091252***
	(0.003928)	(0.006296)	(1.782400)
R-squared	93.65	96.92	99.32
Adjusted R-squared	93.29	96.61	99.25
F-statistic	259***	319***	1493***

Numbers in parentheses are standard errors
*, ** and *** indicate that significant at the 90%, 95% and 99% respectively.

3.3. Estimated effects of projected climate change

Two climate scenarios are applied to predict the impacts of climate change on the gross domestic product in the ASEAN region and its variance for the coming decade. The overview investigates climate projections for 2039, 2059, 2079, and 2099 for a general context of climate change. The climate science community sources a suite of global climate models to help decision-makers understand the projections of future climate change and related impacts. The Coupled Model Intercomparison Project, Phase 5 (CMIP5) models included in the IPCC's Fifth Assessment Report (AR5) are among the most widely used. Key projected climate trends are summarized: temperature by mean annual temperature is projected to increase by 2℃ by 2050. The highest temperature increase is projected for June-August. Warming is projected to be more rapid in the interior regions than in areas close to the coast. The higher warming is projected in the northwest and southeast. The number of consecutive dry days is projected to increase by 5, while the number of frost days decreases by 13. Precipitation: mean annual precipitation is projected to decrease by 11% by 2050. IPCC GCMs precipitations for the ASEAN region indicate a decrease with the greatest reduction during September-November and March-May. Precipitation in June-August is projected to increase by 2%. This section allows the visualization of climate variables and indices derived from scientifically vetted CMIP5 projections for different timeframes, statistics, emission scenarios, and climate models.

Metadata: future climate information is derived from 35 available global circulation models (GCMs) used by the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report. Data is presented at a 1℃x1℃ global grid spacing, produced through bi-linear interpolation. Data snapshots: mean annual temperature rise by 2.32℃ (1.48℃ to 3.66℃) in 2040-2059 (RCP 8.5, Ensemble). Annual precipitation will decrease by-22.17mm (-106.22mm-67.67mm) in 2040-2059 (RCP 8.5, Ensemble).

Table 5 Climate change scenarios.

Temperature		CH	LA	MM	VT	TH	MY	PH
2039	A2	3.53	4.45	4.32	4.21	3.66	3.50	3.34
	B2	2.86	3.67	3.59	3.41	2.83	2.88	2.67
2059	A2	7.27	9.69	8.65	8.75	7.70	6.66	6.37
	B2	4.42	5.82	5.38	5.48	4.46	4.38	4.01
2079	A2	10.35	13.54	11.99	12.26	10.82	8.59	8.40
	B2	5.33	7.04	6.83	6.50	5.55	5.35	4.99
2099	A2	7.26	10.57	9.28	9.13	7.84	5.71	6.02
	B2	5.99	7.60	7.51	7.36	6.06	5.83	5.48
Precipitation								
2039	A2	3.54	3.69	3.30	1.51	6.97	3.10	12.24
	B2	2.02	0.50	0.86	0.95	1.09	2.89	3.63
2059	A2	9.49	-0.74	6.08	-1.02	13.82	1.72	7.91
	B2	2.59	0.94	2.57	1.73	1.71	4.12	3.51
2079	A2	10.77	6.44	8.59	-1.38	22.95	5.53	8.47
	B2	4.20	4.41	4.41	3.33	6.12	4.80	5.88
2099	A2	13.54	-7.28	2.21	-3.13	15.45	1.81	-3.68
	B2	4.56	5.58	5.51	4.14	6.18	6.28	5.39

Percentage change in climate variable for the years 2039, 2059, 2079 and 2099 from the base year this study.

Table 6 Results on the percentage change in GDP in agriculture under projections of climate change

Effect CC (A2)	CH	LA	MM	VT	TH	MY	PH
2039	- 0.19	- 0.24	- 0.24	- 0.23	- 0.19	- 0.19	- 0.17
2059	- 0.29	- 0.39	- 0.36	- 0.36	- 0.30	- 0.29	- 0.26
2079	- 0.35	- 0.46	- 0.45	- 0.43	- 0.36	- 0.35	- 0.33
2099	- 0.39	- 0.50	- 0.49	- 0.49	- 0.40	- 0.38	- 0.36
Effect CC (B2)							
2039	- 0.23	- 0.29	- 0.28	- 0.28	- 0.24	- 0.23	- 0.21
2059	- 0.47	- 0.65	- 0.57	- 0.58	- 0.50	- 0.44	- 0.42
2079	- 0.68	- 0.90	- 0.79	- 0.82	- 0.69	- 0.57	- 0.55
2099	- 0.47	- 0.71	- 0.62	- 0.61	- 0.51	- 0.38	- 0.41

Source: Climate change knowledge portal for development practitioners and policymakers.

The projected climate change scenarios related to the temperature and precipitation for 7 countries in the ASEAN region: Cambodia, Lao PDR, Myanmar, Vietnam, Thailand, Malaysia and the Philippines are presented in Table 5. The simulation reveals a tendency for the average temperature to increase unevenly throughout the region compared to the baseline period in this study (1995-2018). Lao PDR and Vietnam tend to shift towards warmer temperatures, with the estimated rises being 3.67 - 13.54% and 3.41 - 12.26%, respectively, for the A2 and B2 scenarios. For the projections of precipitation change, the trends described by different scenarios go in either direction, increased or decreased, that the precipitation level could be higher or lower, compared to the baseline period. For instance, simulated precipitation levels fluctuate between -3.68 and 12.24% -0.74 - 6.44%, -1.02 and 4.14 for the Philippines, Lao PDR, and Vietnam, respectively. In contrast, the precipitation in Thailand, Cambodia, Myanmar, and Malaysia will be significant, increased for all scenarios by 1.09 to 22.95%, 2.02 to 13.54%, 0.86 to 8.59%, and 1.72 to 6.28%.

To identify the link between GDP in the agriculture sector in the ASEAN region and future climate change, we now extrapolate the national and regional GDP from combining the estimation results of climate-related elasticities in the previous section with simulated temperature and levels under (IPCC) future climate scenarios.

The potential effects of climate change on GDP in the agriculture sector in the ASEAN region are presented by the percentage of GDP in the agriculture sector. The estimates are shown in Table 6. For the A2 scenario, GDP in the agriculture sector drops by 0.24% in 2039, followed by declines of 39%, 46% and 50% for 2059, 2079 and 2099, respectively. Similar results have been obtained for the B2 scenario where GDP in agriculture sector drop by 0.29%, 0.65%, 0.90% and 0.71% in 2039, 2059, 2079 and 2099, respectively. In general, future climate change leads to an overall decrease in GDP in the agriculture sector, particularly in Lao PDR, where the decline in the agriculture sector ranges from 0.27% to 0.90%. Overall, the simulation results of climate change projections reveal an increase in GDP in the agriculture sector uncertainties in the future. For instance, Rosenzweig et al. (2014) found that agricultural yields predominantly suffer due to adverse environmental conditions in developing countries. Therefore, high temperatures and excess CO_2 accumulation force scientists to devise new strategies to cope with less predictable challenges. Another study by Ashraf et al. (2018) showed that Eco-physiological stresses greatly influence plant growth and yield. Under natural climate conditions, plants often experience numerous stresses like waterlogging, drought, heat, cold, and salinity. Altieri and Nicholls. (2017) assessed that developed countries are more vulnerable to climatic change (8-11%) than developing countries. UNICEF and Organization. (2017) investigated the effects of climate change and environmental variation are mainly estimated by the number of stress spells, their impact on daily life, and damage to agriculture crops. Arunanondchai et al. (2018) identified that the natural systems, human health, and agricultural production had been badly affected by devastating environmental change.

4. Conclusion

In this study, we investigate the effects of climate change on GDP in the agriculture sector in the ASEAN region includes: Cambodia, Lao PDR, Myanmar, Vietnam, Thailand, Malaysia and, the Philippines, providing helpful information for effect to sustain GDP in the agriculture sector in the future. The empirical estimation results indicate that climate change influences GDP in the agriculture sector through temperature and precipitation. We found that that temperature rise reduces GDP in the agriculture sector. We also estimated the effect of precipitation level increase and found that an increase in precipitation boosts the GPD in the agriculture sector, but we accessed that variance precipitation decrease GDP in the agriculture sector. The combination of estimated effects of climate change on GDP in the agriculture sector and projected climate scenarios allows us to simulate future climate change's possible impact on GDP in the agriculture sector in the ASEAN region. Under A2 & B2 scenarios, GDP in the agriculture sector falls almost every time of years 2039, 2059, 2079 and 2099 in every 7 countries in the ASEAN. Based on estimation results, if the policymaker is concerned about climate change actions, it will help more comprehensive risk decision-making, and policy exertions should be concentrated toward climate change to GDP in the agriculture sector in the ASEAN region. Besides significantly contributing to the estimates of potential impacts of climate change and non-climatic variables on the GDP in the agriculture sector in the ASEAN region to the existing literature, the study also raises several issues which could be further investigated. After getting the empirical result, the policymaker can develop and evaluate strategic policy responses with a view to how societies in the ASEAN region might respond to the potential impacts of climate change identified in the previous phase to protect their environmental and natural resource base, their economic vitality, and their prosperity. Improve federal coordination and policy evaluation by establishing clear leadership, responsibilities, and coordination for climate-related decisions, information systems, and services at the federal level. Establish information and reporting systems that allow for regular evaluation and assessment of the effectiveness of both government and non-gov-ornamental responses to climate change. Assess, evaluate, and learn from the different approaches to climate-related decision-making used by non-federal levels of government and the private sector.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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