SAJAAS

Southeast Asian Journal of Agriculture and Allied Sciences

Volume 3 Issue 1

Modeling the Impact of Country-Specific Warming on Agricultural Production: Evidence from Southeast Asian Economies

Zoleta, Aris C.[1]

[1]Lecturer, Institute of Management, Bulacan Agricultural State College, San Ildefonso Bulacan
[1]Economist, Economic Research, Macroeconomic Research, Asian Development Bank, Mandaluyong City, Metro Manila

pp. 39-50

SAJAAS Southeast Asian Journal of Agriculture and Allied Sciences
Bulacan Agricultural State College

Modeling the Impact of Country-Specific Warming on Agricultural Production: Evidence from Southeast Asian Economies

Zoleta, Aris C.[1]

Abstract

This research explored the relationship between climate change and agricultural production in Southeast Asian economies. Using country-specific ordinary least squares (OLS) regression and panel data analysis, the study modeled the factors that could explain how temperature variations affect agricultural output across the region. The findings indicate that the impact of temperature variability on agricultural productivity is not definitively clear. In addition, Cambodia, Lao PDR, Myanmar, and Vietnam are particularly susceptible to agricultural output losses due to rising temperatures in the region.

Keywords: *Agricultural Production, Climate Change, Precipitation, Southeast Asia, Temperature*

Introduction

Southeast Asian economies ("region") agricultural production is among the most vulnerable to climate change. To this date, several studies have been conducted to study the impact of climate change on economic growth among Southeast Asian economies. However, there is limited understanding and comprehensive studies on how climate change impacts Southeast Asian agricultural production. Despite the region's rapid industrialization, agriculture continues to be an important sector of the economy. Given these facts, it is undeniable that climate change has a profound impact on Southeast Asian agricultural production.

The effects of increasing warming in the region are more visible with different crops. Despite the reduction in crop yields due to temperature variation, varietal choices impact how crops adapt to temperature changes. This makes the impact of extreme temperatures highly localized. For example, an analysis of U.S. soybean production found that temperature changes beyond the usual range led to a 2.4% decrease in soybean yield in the Southern states, whereas the Midwest saw a 1.7% increase in yield (Hatfield et al. 2011). Besides the local effect of temperature change, other studies, such as Welch et al. (2010), found that temperature variation significantly affects rice growth during the vegetative and ripening stages; higher minimum temperatures reduce yield while higher maximum temperatures raise it. Ghosh et al. (2000) demonstrate that an increase in temperature reduces both the quality and quantity of dry matter like potatoes. Similar results in other crops like tomatoes and lettuce show that temperature variation reduces crop yield (Dufault et al., 2009; Pressman et al., 2002).

One area of literature focuses on the impact of climate change on agricultural production in developing countries (Fankhauser & Tol, 1997; Mendelsohn et al., 2006; Rosenzweig & Parry, 1994). The reliance of developing economies on agriculture, coupled with limited climate adaptation and technology, makes these countries more susceptible to the effects of climate change. Raj et al.(2022) emphasized that policies for climate adaptation should prioritize food production and accessibility in areas

[1] Lecturer, Institute of Management, Bulacan Agricultural State College San Ildefonso Bulacan
[1] Economist, Economic Research, Macroeconomic Research, Asian Development Bank, Mandaluyong City, Metro Manila

where small subsistence farmers are from the majority of rural populations. Increasing agricultural productivity is essential for reducing income inequality between urban and rural areas as well as ensuring food security. Conversely, Webber et. al (2020) suggest that despite clear evidence linking extreme weather events to crop failures, there is little indication regarding localized crop failure drivers. Large unexplained variations in local yields are likely driven by non-weather-related factors such as pests, weeds, nutrient management, or possible interactions between weather conditions and different agronomic practices leading to local yield failures.

The rapid population growth and economic expansion in the region are placing pressure on agricultural production to meet the increasing demand for food products. According to Venkatappa et al. (2021), approximately 19.9 million ha of croplands in the ASEAN region experienced severe drought conditions, while 3.6 million ha faced potential flood damage due to heavier-than-usual precipitation. Effective climate policies that address adaptation, mitigation, and carbon emissions must be developed within regional frameworks and through cooperation among nations. Despite the declining share of agriculture in each ASEAN country, it is expected that the impact of climate change will remain significant due to an increased reliance on agricultural imports over the coming decades as highlighted by Zhai and Zhuang (2009). This dependence could lead these economies to suffer from welfare losses stemming from deteriorating terms of trade with negative effects predicted for countries like the Philippines, Indonesia, Thailand, and Vietnam but less so for Singapore and Malaysia. Therefore, it is crucial to consider climate change and its impact on temperature variation and precipitation when analyzing agricultural production in ASEAN countries.

This paper aims to fill a gap and contribute to the literature in several dimensions. First, although there is a growing body of evidence and studies related to the impact of climate change, there remains a limited understanding of the mechanisms by which this could affect agricultural production at the regional or local level. The diverse characteristics of regional agriculture can lead to a vague understanding of the severity of climate impacts on agricultural production. To address this issue, the study introduces both country-specific and regional climate variables into the empirical model. Second, by using a panel of selected ASEAN economies, the paper provides evidence on the impact of climate change on agricultural production in the region. Finally, the existing literature often assumes that climate and weather conditions are identical shocks driving changes in agricultural production. This study challenges that assumption by defining weather and climate variables as distinct exogenous shocks in the empirical model. This approach accounts for the unique individual effects of local temperature changes versus global temperature changes on agricultural production in each ASEAN country.

Against this backdrop, the study investigated the impact of climate change on Southeast Asian economies, examining the impact of climate change on Southeast Asian agriculture with a focus on comparing country-specific warming against global warming.

Materials and Method

Empirical Model

The study employed country-specific ordinary least square (OLS) regression and panel data regression for Southeast Asian economies. The OLS method seeks to minimize the sum of the squared differences between the observed values and the predicted values. The produce coefficient in the OLS regression can be interpreted as the effects of the independent variables on the dependent variables.

Generally, the OLS regression in this paper can be described as,

$$y_t = \kappa z_t + \beta x_t + \varepsilon_t \quad (1)$$

To complement the OLS regression, the study also employed panel regression, which allows for the examination of dynamic changes across units and time. The data-generating process and coefficient which is the interest of this study, allows the paper to investigate the effects of country-specific warming on the region's agricultural production accounting for differences in each unit or country in the panel regression. The panel regression model can be described as,

$$y_{j,t} = \kappa z_{j,t} + \beta x_{j,t} + \delta_j + \varepsilon_{j,t} \quad (2)$$

For robustness, the study also employed two types of panel models, (1) fixed effects (FE) and random effects (RE). FE model removes the unit's specific and time-invariant properties so the author can assess the net effects of the independent to dependent variables. Without controlling the FE, the regression result could potentially be biased. If the individual or country-specific effects are strictly uncorrelated with the independent variables, it may be suitable to model the individual or country-specific constant terms as randomly distributed across the cross-sectional units. RE accounts for the time-invariant unit-specific characteristic in the regression model, in FE this is absorbed in the model intercept.

In Equation (1) and (2), y_j is the region's or country's agricultural production; z_t represents the climate variables; x_t denotes the control variables that are relevant to agricultural production; δ_j are the country's fixed effects and ε_j is the error term.

The selection of climate variables and control variables is based on the existing literature, with temperature change, precipitation, and carbon emissions used as climate variables, and land and labor included as control variables. Understanding the mechanisms and channels through which shocks from both country-specific warming and global warming are propagated and how they amplify climate change risk is important in mitigating the negative effects of climate change on Southeast Asian agricultural production.

Data Collection

Annual time series were collected from 1991 to 2021 from the World Bank Development Indicator, Word Bank Climate Knowledge Portal, and Food and Agricultural Office. Table 1 in the Appendix details the data sources and definitions.

Results and Discussion

Benchmark Panel Model and Country OLS Regression

The benchmark model assumes a contemporaneous impact on Southeast Asian agricultural production. Table 2 in the Appendix displays the results of both panel and country-specific OLS regressions. The findings align with the earlier literature, indicating that most Southeast Asian countries could experience a negative impact from rising temperatures, except for Brunei Darussalam and Lao PDR. This is statistically significant for Malaysia, Myanmar, and the Philippines. Furthermore, the panel results demonstrate that ASEAN agricultural production is negatively affected by rising temperatures;

Singapore has the highest negative coefficient.

The paper's results show that an increase in arable land positively contributes to agricultural production in Southeast Asia, except for Myanmar. This effect is statistically significant for Brunei Darussalam, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, and Vietnam, as well as for ASEAN as a group. These findings highlight the crucial role of soil and land use in achieving the region's goals of reducing carbon emissions and promoting sustainable agricultural practices. Despite the urgent need to boost farm output, additional food production must not involve expanding agricultural land, to protect natural ecosystems essential for biodiversity and climate change mitigation. The ASEAN (2023) stresses the importance of developing a regional land use framework and ensuring the sustainable production of agricultural inputs from available sources within the region. However, due to the region's economic growth, the amount of arable land continues to decline because of urbanization, industrialization, and soil degradation.

The labor share in agriculture yields intriguing results that warrant further examination. In Southeast Asia, an increase in labor share is found to negatively impact agricultural production, with statistically significant effects in countries such as Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, the Philippines, Thailand, and Vietnam. These findings may be linked to the global trend of rural migration to urban centers and cities. Employment in agriculture has been steadily declining, with an average annual decrease of 1.6 percent between 2015 and 2021, resulting in a reduction of approximately 164 million people in the Asia-Pacific region. This trend marks a significant reversal from the 1960s and 1970s, when the majority of the population lived in rural areas, compared to today, where most now reside in cities and other urban areas (FAO, 2020; ILO, 2022).

These findings underscore the complex relationship between temperature, arable land, labor share, and agricultural production in the region. Rising temperatures lead to reduced agricultural yields, which in turn drive rural migration to urban centers, decreasing the availability of labor on farms and further diminishing agricultural output. Addressing this intricate and complex issue requires careful policy design to counter the decline in agricultural productivity in the region.

The impact of precipitation and CO2 emissions on agricultural production varies among the 10 Southeast Asian economies. The relationship between agricultural production and precipitation is positive for Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, and Vietnam. However, it is negative for Malaysia, Singapore, and Thailand. Additionally, as a group, ASEAN has a statistically significant negative relationship with precipitation. Similarly, the effect of CO2 emissions on Southeast Asian agricultural production is mixed. In Indonesia, Lao PDR, the Philippines, and Singapore, an increase in emissions leads to a reduction in agricultural output. However, in Brunei Darussalam, Cambodia, Malaysia, Myanmar, Thailand, and Vietnam, an increase in CO2 emission improves agricultural output. The results are statistically significant for Brunei Darussalam, Malaysia, and the Philippines. Surprisingly, ASEAN as a group exhibits the least coefficient.

Effects of Country-specific Warming Panel Model with Fixed and Random Effect

Table 3 in the Appendix shows the regression results with fixed and random effects. In terms of other climate variables, precipitation is statistically significant for all groups, indicating that an increase in precipitation leads to a reduction in agricultural output except for Developing Southeast Asia. CO2 emissions also show a statistically significant and positive relationship for all groups except for Developing Southeast Asia with FE.

In comparison, it is evident that Developing Southeast Asia as a group is the most vulnerable to increasing warming. Countries such as Cambodia, Myanmar, Lao PDR, and Vietnam are among the most productive rice producers in the region, especially when considering arable land use for agricultural production. Comparing the results, Developing Southeast Asia has the largest coefficient. The significant potential of Developing Southeast Asia to contribute to the region's food security cannot be overlooked.

To further validate the paper's findings, similar regression models were conducted for rice and maize production. Tables 4 and 5 in the Appendix present the regression results for these two crucial crops in the region. The findings indicate that rice and maize production in developing Southeast Asian countries is more vulnerable to rising temperatures compared to ASEAN-5 plus Brunei. This vulnerability is particularly pronounced in Cambodia, Myanmar, Lao PDR, and Vietnam, which are major rice and maize producers in the region. The regression results underscore the asymmetry of climate change impacts across the region. The lack of regional cooperation and efforts to address climate change exacerbates the risks to agricultural production. Without a committed regional plan to reduce emissions, and with national development priorities taking precedence over environmental protection, developing ASEAN members such as Cambodia, Myanmar, and Lao PDR face further risks from climate change (Islam & Kieu, 2020). Largely, the results of the paper are similar to the literature results on the impact of climate change on regions' agricultural production (Nunti et al., 2020; Zhai & Zhuang, 2009)

Effects of Global Warming

Table 6 in the Appendix presents the regression performed using alternative measures of global warming, as in Table 3. The benchmark model exposes each country in the panel to country-specific shocks in temperature variability. The difference in regression presented in Table 6 indicates a common shock in temperature variability within the region. Despite the modification in the benchmark empirical model to account for the common warming shock, the results reported in Table 6 are consistent with the observed results in Table 3 in which country-specific warming is the treatment variable. In other words, there is no significant change in results whether the empirical model will use NASA or NOAA as definitions of global warming.

Comparing the results of various versions of the benchmark empirical model reveals that the model including ASEAN 5 + Brunei is the most influenced by increased precipitation and global warming. The countries in this group, which are most affected by warming, respond by expanding irrigation infrastructure, investing in drought-tolerant crop varieties, scaling up operations, developing technologies and best practices to enhance yield and productivity, and continuing to invest in sustainable agricultural production (FAO, 2016).

Conclusion

The findings of this study highlight the substantial influence of climate change, especially rising temperatures, on agricultural output in Southeast Asia. Although the results are inconclusive in the impact of temperature variation on agricultural production in the region, it is evident that increasing temperatures alone do not necessarily lead to negative impacts on agricultural productivity. Elevated levels of CO2 emissions and warmer temperatures have been observed to enhance growth and yields, particularly for temperate and perennial crops such as rice and maize. However, it is important to note that the beneficial effects of warming temperatures are contingent upon various factors, including access to irrigation, varietal improvement, farm practices, and the availability of other agricultural technologies. Therefore, while warming temperatures may have some positive outcomes for agricultural production, the paper shows that there is a lot of complexity in the interaction of temperature and agricultural production.

References

ASEAN. (2023). ASEAN Regional Guidelines for Sustainable Agriculture in ASEAN. *ASEAN-CRN*. https://asean-crn.org/asean-regional-guidelines-for-sustainable-agriculture-in-asean/

Dufault, R. J., Ward, B., & Hassell, R. L. (2009). Dynamic relationships between field temperatures and romaine lettuce yield and head quality. *Scientia Horticulturae*, *120*(4), 452–459. 10.1016/j.scienta.2009.01.002

Fankhauser, S., & Tol, R. S. J. (1997). The Social Costs of Climate Change: The IPCC Second Assessment Report and Beyond. *Mitigation and Adaptation Strategies for Global Change*, *1*(4), 385–403. https://doi.org/10.1023/B:MITI.0000027387.05917.ae

FAO. (2016). *Strategic Plan of Action for ASEAN Cooperation in Crops, 2016-2020.* **|** *FAOLEX*. https://www.fao.org/faolex/results/details/en/c/LEX-FAOC197568/

FAO. (2020). *Agricultural research in Southeast Asia.* **|** *FAO*. https://www.fao.org/family-farming/detail/en/c/1333395/

Ghosh, S. C., Asanuma, K., Kusutani, A., & Toyota, M. (2000). Effects of Temperature at Different Growth Stages on Nonstructural Carbohydrate, Nitrate Reductase Activity and Yield of Potato. *Environment Control in Biology*, *38*(4), 197–206. https://doi.org/10.2525/ecb1963.38.197

Hatfield, J. L., Boote, K. J., Kimball, B. A., Ziska, L. H., Izaurralde, R. C., Ort, D., Thomson, A. M., & Wolfe, D. (2011). Climate Impacts on Agriculture: Implications for Crop Production. *Agronomy Journal*, *103*(2), 351–370. https://doi.org/10.2134/agronj2010.0303

ILO. (2022). *Asia–Pacific Sectoral Labour Market Profile: Agriculture* **|** *International Labour Organization*. https://www.ilo.org/resource/brief/asia-pacific-sectoral-labour-market-profile-agriculture

Islam, M. S., & Kieu, E. (2020). Tackling Regional Climate Change Impacts and Food Security Issues: A Critical Analysis across ASEAN, PIF, and SAARC. *Sustainability*, *12*(3), 883 (page). https://doi.org/10.3390/su12030883

Mendelsohn, R., Dinar, A., & Williams, L. (2006). The distributional impact of climate change on rich and poor countries. *Environment and Development Economics*, *11*(2), 159–178. doi:10.1017/S1355770X05002755

Nunti, C., Somboon, K., & Intapan, C. (2020). The Impact of Climate Change on Agriculture Sector in ASEAN. *Journal of Physics: Conference Series*, *1651*(1), 012026. https://doi.org/10.1088/1742-6596/1651/1/012026

Pressman, E., Peet, M., & Pharr, M. (2002). The Effect of Heat Stress on Tomato Pollen Characteristics is Associated with Changes in Carbohydrate Concentration in the Developing Anthers. *Annals of Botany*, *90*(5), 631–636. https://doi.org/10.1093/aob/mcf240

Raj, S., Roodbar, S., Brinkley, C., & Wolfe, D. W. (2022). Food Security and Climate Change: Differences in Impacts and Adaptation Strategies for Rural Communities in the Global South and North. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.691191

Rosenzweig, C., & Parry, M. L. (1994). Potential impact of climate change on world food supply. *Nature*, *367*(6459), 133–138. https://doi.org/10.1038/367133a0

Venkatappa, M., Sasaki, N., Huang, J., & Phoumin, H. (2021). Impacts of Climate Change on Agriculture in South-East Asia—Drought Conditions and Crop Damage Assessment. In H. Phoumin, F. Taghizadeh-Hesary, F. Kimura, & J. Arima (Eds.), *Energy Sustainability and Climate Change in ASEAN* (pp. 3–38). Springer. https://doi.org/10.1007/978-981-16-2000-3_1

Webber, H., Lischeid, G., Sommer, M., Finger, R., Nendel, C., Gaiser, T., & Ewert, F. (2020). No perfect storm for crop yield failure in Germany. *Environmental Research Letters*, *15*(10), 104012. https://doi.org/10.1088/1748-9326/aba2a4

Welch, J. R., Vincent, J. R., Auffhammer, M., Moya, P. F., Dobermann, A., & Dawe, D. (2010). Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. *Proceedings of the National Academy of Sciences*, *107*(33), 14562–14567. https://doi.org/10.1073/pnas.1001222107

Zhai, F., & Zhuang, J. (2009). *Agricultural Impact of Climate Change: A General Equilibrium Analysis with Special Reference to Southeast Asia*. *131*. https://www.adb.org/publications/agricultural-impact-climate-change-general-equilibrium-analysis-special-reference

Appendix

Table 1

Description of Variables

Variable	Definition	Data Source
Country Specific Variable		
Agricultural production	The FAO indices of agricultural production show the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 2014-2016. Indices for meat production are computed based on data for production from indigenous animals.	The data on the agricultural production index is downloaded from FAO metadata https://www.fao.org/faostat/en/#data/OEA/metadata
Labor Share of Agriculture	Employment in agriculture, forestry, and fishing by age: The indicator corresponds to the ILOSTAT indicator "Employment by sex, age, and economic activity (thousands) – Annual "for the agriculture, forestry, and fishing sector which is defined by the Section A of ISIC classification. Employment comprises all persons of working age who during a specified brief period, such as one week or one day, were in the following categories: a) paid employment (whether at work or with a job but not at work) or b) self-employment (whether at work or with an enterprise but not at work). Employment in agriculture, forestry, and fishing by status of employment	Labor share of agriculture is sourced from FAO metadata https://www.fao.org/faostat/en/#data/OEA/metadata
Arable Land	The FAOSTAT Land Use domain contains data on forty-four categories of land use, irrigation, and agricultural practices and five indicators relevant to monitoring agriculture, forestry, and fisheries activities at the national, regional, and global levels. Data are available by country and year, with global coverage and annual updates.	Land use is downloaded from FAO metadata https://www.fao.org/faostat/en/#data/RL/metadata
Precipitation	Average precipitation in depth (mm per year). Average precipitation is the long-term average in depth (over space and time) of annual precipitation in the country. Precipitation is defined as any kind of water that falls from clouds as a liquid or a solid.	Data for the precipitation were downloaded from https://climateknowledgeportal.worldbank.org/

Country Temperature	The mean temperature is defined as the average between the max and min temperature in the day. The expected temperature in degrees, is valid for the indicated hour. Global temperature is an average of air temperature recordings from weather stations on land and sea as well as some satellite measurements. Extreme temperature events (i.e., maximum, minimum) may have short-term durations of a few days with temperature increases of over 5°C above the normal temperatures.	Data for the temperature is source from download from https://climateknowledgeportal.worldbank.org/
CO_2 Emission	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	The series for the CO_2 emission is sourced from Word Bank Development Indicator https://databank.worldbank.org/source/world-development-indicators
Global Variable		
NASA Global Temperature	NASA collects temperature data on changes in global surface temperature compared to the long-term average from 1951 to 1980. Earth's average surface temperature in 2023 was the warmest on record since recordkeeping began in 1880	The series is collected from NASA website https://climate.nasa.gov/vital-signs/global-temperature/?intent=121.
NOAA Global Temperature Anomalies	Temperature data were collected from manual and automated weather stations. Quality-checked data become part of the Global Historical Climatology Network-Monthly (GHCN-M) data set and the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). A combined global land and ocean temperature anomaly dataset was created from these resources.	The time series is collected from NOAA website https://www.climate.gov/maps-data/dataset/global-temperature-anomalies-graphing-tool

Note: Data definition is mostly quoted from the source website

Table 2

Panel Regression with Fixed Effect and Country OLS Results
Region and Country's Agricultural Production

	ASEAN	BRN	CAM	IND	LAO	MYS	MYN	PHL	SGP	THA	VTM
Labor Share of Agriculture	-0.015*** (0.002)	-1.0560 *** (-3.756)	-0.0211 * (-2.421)	-0.0135 *** (-3.918)	-0.0594 *** (-4.310)	-0.0143 (-1.758)	-11.4470 (-0.951)	-0.0257 *** (-6.826)	-0.5664 (-1.133)	9.767 *** (0.255)	0.0042 (0.734)
Arable Land	0.036*** (0.006)	5.2241 *** (4.335)	1.5713 (1.686)	1.5111 *** (6.540)	0.93677 * (2.340)	1.1460 *** (7.347)	-0.0511 *** (-4.560)	1.5125 *** (4.408)	0.8309 (1.189)	5.873 (5.660)	0.8819 ** (3.482)
Precipitation	-0.556*** (0.103)	0.2058 (0.426)	0.1256 (0.611)	0.0737 (0.614)	0.17578 (1.079)	-0.0167 (-0.178)	1.5779 (1.990)	0.0510 (0.777)	-1.1288 (-1.810)	-4.305 (-0.387)	0.1374 (0.861)
C02 Emission	-0.017 (0.027)	1.0216 * (2.345)	0.1445 (1.227)	-0.0810 (-0.557)	-0.0876 (-0.963)	0.5478 *** (5.170)	0.23463 (0.796)	-0.2525 ** (-3.364)	-1.1464 (-0.721)	2.433 (1.939)	0.3541 (2.738)
Country Temperature	-0.509 (0.433)	2.0236 (0.569)	-3.0600 (-1.424)	-1.0200 (-0.460)	1.0073 (0.785)	-5.1903 ** (-3.631)	-0.2242 ** (-3.318)	-3.7843 ** (-3.009)	-23.0475 (-1.715)	-6.213 (-0.691)	-1.4076 (-1.813)
Constant	–	-18.7036 (-1.528)	1.2048 (0.107)	- 8.7432 (-1.124)	-3.4286 (-0.618)	10.4990 * (2.078)	0.52320 (0.214)	3.0659 *** (0.539)	93.1098 (1.937)	-5.235 *** (-5.103)	-0.6392 (-0.178)
Observations	270	24	24	24	24	24	24	24	24	24	24
R-squared	0.374	0.7927	0.968	0.9765	0.9848	0.9801	0.933	0.9691	0.2563	0.9533	0.9876
No. of Country	10	1	1	1	1	1	1	1	1	1	1

Note: The result is based on the benchmark model $y_{i,t} = labor_{i,t} + land_{i,t} + prec_{i,t} + CO2_{i,t} + ctry\_temp_{i,t}$ $***\ p > 0.001$ $**\ p > 0.01$ $*\ p > 0.05$. All variables are in the log except the labor share of agriculture. The one in () is the t-statistic. Where $y_{i,t}$ is the country's FAO agricultural production index. Country and panel OLS regression is from 1991-2020. BRN = Brunei Darussalam, CAM = Cambodia, IND = Indonesia, LAO = Lao PDR, MYS = Malaysia, MYN = Myanmar, PHL = Philippines, SGP = Singapore, THA = Thailand and VTM = Viet Nam.

Table 3

Country-Specific Warming Panel Regression with Fixed Effect and Random Effects The Region, ASEAN 5 + BRN and Developing ASEAN Agricultural Production

	ASEAN		ASEAN 5 + BRN		Developing Southeast Asia	
Variables	**FE**	**RE**	**FE**	**RE**	**FE**	**RE**
Labor Share of Agriculture	-0.012*** (0.001)	-0.015*** (0.001)	-0.030*** (0.003)	-0.022*** (0.002)	-0.006 (0.009)	-0.033*** (0.003)
Arable Land	-0.003 (0.005)	0.006 (0.006)	0.078*** (0.020)	0.015 (0.013)	-0.001 (0.037)	0.021 (0.031)
Precipitation	-0.309*** (0.075)	-0.354*** (0.082)	-0.788*** (0.253)	-0.390** (0.161)	0.060 (0.328)	0.401** (0.193)
C02 Emission	0.040** (0.017)	0.097*** (0.019)	0.441*** (0.067)	0.253*** (0.046)	-0.010 (0.093)	0.128*** (0.040)
Country Temperature	0.707* (0.372)	0.440 (0.446)	13.143*** (3.693)	3.765* (2.223)	-1.791 (1.283)	2.162*** (0.510)
Constant	_	6.098*** (1.707)	_	-4.704 (8.055)	_	-3.845* (2.243)
Observations	270	270	150	150	90	90
R-squared	0.551	0.581	0.480	0.501	0.666	0.869
No. of Country	10	10	6	6	4	4

Note: The result is based on the lag model $y_{i,t} = labor_{i,t} + land_{i,t-1} + prec_{i,t-1} + CO2_{i,t-1} + ctry\_temp_{i,t-1}$ $*** \ p > 0.001$ $** \ p > 0.01$ $* \ p > 0.05$. All variables are in the log except the labor share of agriculture. The one in () is the t-statistic. Where $y_{i,t}$ is the region's FAO agricultural production index. Panel regression is from 1991-2020. FE = Fixed Effect and RE = Random Effect. ASEAN 5 is the 4 middle-income countries of IND = Indonesia, MYS = Malaysia, PHL = Philippines, THA = Thailand, and a developed economy of SGP = Singapore. BRN = Brunei. Developing Southeast Asia is defined as CAM = Cambodia, LAO = Lao PDR, MYN = Myanmar, and VTM = Viet Nam.

Table 4

Country-Specific Warming Panel Regression with Fixed Effect and Random Effects The Region, ASEAN 5 + BRN and Developing ASEAN's Rice Production

	ASEAN		ASEAN 5 + BRN		Developing Southeast Asia	
	FE	**RE**	**FE**	**RE**	**FE**	**RE**
Labor Share of Agriculture	-0.005 (0.003)	-0.009*** (0.003)	0.063*** (0.006)	0.031*** (0.005)	-0.011** (0.005)	-0.034*** (0.002)
Arable Land	-0.058*** (0.016)	-0.046*** (0.016)	-0.174*** (0.036)	-0.046 (0.034)	0.108*** (0.027)	0.092*** (0.031)
Precipitation	-2.956*** (0.208)	-2.434*** (0.206)	2.580*** (0.438)	3.075*** (0.319)	-0.601** (0.281)	-0.340* (0.206)
Country Temperature	12.342*** (1.065)	12.141*** (1.080)	-14.492* (8.009)	23.572*** (5.438)	-17.024*** (0.748)	-13.393*** (0.419)
Constant	_	-3.700 (3.869)	_	-86.179*** (19.230)	_	63.438*** (2.239)
Observations	240	240	120	120	90	90
R-squared	0.629	0.549	0.935	0.843	0.992	0.976
No. of Country	10	10	6	6	4	4

The result is based on the lag model. $y_{i,t} = labor_{i,t} + land_{i,t-1} + prec_{i,t-1} + ctry\_temp_{i,t-1}$ $*** \ p > 0.001$ $** \ p > 0.01$ $* \ p > 0.05$. All variables are in the log except the labor share of agriculture. The one in () is the t-statistic. Where $y_{i,t}$ is the region's FAO rice production data. Panel regression is from 1991-2020. FE = Fixed Effect and RE = Random Effect. ASEAN 5 is the 4 middle-income countries of IND = Indonesia, MYS = Malaysia, PHL = Philippines, THA = Thailand, and a developed economy of SGP = Singapore. BRN = Brunei. Developing Southeast Asia is defined as CAM = Cambodia, LAO = Lao PDR, MYN = Myanmar, and VTM = Viet Nam.

Table 5

Country-Specific Warming Panel Regression with Fixed Effect and Random Effects
The Region, ASEAN 5 + BRN and Developing ASEAN's Maize Production

	ASEAN		**ASEAN 5 + BRN**		**Developing Southeast Asia**	
	FE	**RE**	**FE**	**RE**	**FE**	**RE**
Labor Share of	-0.019***	-0.026***	0.183***	0.110***	0.028**	-0.077***
Agriculture	(0.005)	(0.004)	(0.014)	(0.011)	(0.014)	(0.005)
Arable Land	0.078***	0.092***	0.094	0.325***	0.731***	0.643***
	(0.026)	(0.026)	(0.076)	(0.072)	(0.074)	(0.081)
Precipitation	-1.847***	-1.253***	5.160***	6.578***	-1.274	0.302
	(0.346)	(0.327)	(0.929)	(0.670)	(0.787)	(0.534)
Country	28.589***	28.486***	10.358	85.260**	-16.327***	-1.058
Temperature	(1.769)	(1.718)	(17.002)	(11.422)	(2.093)	(1.096)
Constant	_	-68.708***	_	120	_	14.135**
		(6.154)		0.789		(5.819)
Observations	240	240	120	150	90	90
R-squared	0.586	0.563	0.910	0.501	0.904	0.859
No. of Country	10	10	6	6	4	4

Note: The result is based on the lag model $y_{i,t} = labor_{i,t} + land_{i,t-1} + prec_{i,t-1} + ctry\_temp_{i,t-1}$ $***\ p > 0.001$ $**\ p > 0.01$ $*\ p > 0.05$. All variables are in the log except the labor share of agriculture. The one in () is the t-statistic. Where $y_{i,t}$ is the region's FAO maize production data. Panel regression is from 1991-2020. FE = Fixed Effect and RE = Random Effect. ASEAN 5 is the 4 middle-income countries of IND = Indonesia, MYS = Malaysia, PHL = Philippines, THA = Thailand, and a developed economy of SGP = Singapore. BRN = Brunei. Developing Southeast Asia is defined as CAM = Cambodia, LAO = Lao PDR, MYN = Myanmar, and VTM = Viet Nam.

Table 6

Global Warming Panel Regression with Random Effects
The Region, ASEAN 5 + BRN and Developing ASEAN Agricultural Production

	ASEAN		**ASEAN 5 + BRN**		**Developing Southeast Asia**	
Variables	**NASA**	**NOAA**	**NASA**	**NOAA**	**NASA**	**NOAA**
Labor Share of	-0.012***	-0.013***	-0.024***	-0.023***	-0.021***	-0.021***
Agriculture	(0.001)	(0.001)	(0.003)	(0.003)	(0.002)	(0.002)
Arable Land	-0.002	-0.001	-0.002	-0.002	0.035	0.043
	(0.005)	(0.005)	(0.007)	(0.007)	(0.031)	(0.030)
Precipitation	-0.290***	-0.334***	-0.535***	-0.523***	0.185	0.106
	(0.071)	(0.071)	(0.145)	(0.142)	(0.190)	(0.191)
C02 Emission	0.063***	0.069***	0.298***	0.285***	0.124***	0.136***
	(0.015)	(0.014)	(0.055)	(0.051)	(0.041)	(0.039)
Global	0.383***	0.303***	-0.022	0.001	0.341***	0.257***
Temperature	(0.043)	(0.034)	(0.062)	(0.048)	(0.085)	(0.063)
Constant	7.223***	7.399***	8.892***	8.816***	4.030***	4.434***
	(0.552)	(0.551)	(1.105)	(1.085)	(1.398)	(1.403)
Observations	270	270	150	150	90	90
R-squared	0.678	0.678	0.491	0.491	0.867	0.868
No. of Country	10	10	6	6	4	4

Note: The result is based on the lag model $y_{i,t} = labor_{i,t} + land_{i,t-1} + prec_{i,t-1} + CO2_{i,t-1} + global\_temp_{i,t-1}$ $***\ p > 0.001$ $**\ p > 0.01$ $*\ p > 0.05$. All variables are in the log except the labor share of agriculture. The one in () is the t-statistic. Where $y_{i,t}$ is the region's FAO agricultural production index. Panel regression is from 1991-2020. FE = Fixed Effect and RE = Random Effect. ASEAN 5 is the 4 middle-income countries of IND = Indonesia, MYS = Malaysia = Philippines, THA = Thailand, and a developed economy of SGP = Singapore. BRN = Brunei. Developing Southeast Asia is defined as CAM = Cambodia, LAO = Lao PDR, MYN = Myanmar, and VTM = Viet Nam. Global temperature is primarily collected by NASA = National Aeronautics and Space Administration and NOAA = National Oceanic and Atmospheric Administration.