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# Impact of seasonal rainfall on economic growth in Thailand

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## Abstract

The effects of climate change are significant in terms of rainfall variation. This article contributes to the literature by investigating the impacts of seasonal rainfall on the gross provincial product (GPP) growth rates of provinces in Thailand by using panel data from 1995 to 2015, and a fixed effects model was used for the regression. The estimates suggest that rainfall in summer has the most significant negative impacts on the region of southern Thailand because this region has the highest volume of rainfall and is affected by the monsoon in summer, whereas the central region and the Bangkok Metropolitan Region benefit from the summer rainfall. These results show that seasonal rainfall has an impact on the economic growth inequality throughout the nation.

**JEL classification numbers:** O44, O47, Q54
**Keywords:** Rainfall, Economic growth, Fixed effect model

## 1. Introduction

For centuries, researchers have considered whether and how climate conditions, such as temperature, rainfall, and violent storms, influence the nature of societies and economic performance [1]. This is consistent with Berlemann and Wenzel [2], who suggested that economic sectors are affected by the phenomenon of climate change, resulting in the rediscovery that climate conditions are potential determinants of economic activity. Temperature and rainfall are two climatic variables that are typically represented in economic growth models, but there is greater focus on temperature. The available literature suggests that temperature increases negatively affect economic growth [3-5], whereas rainfall can have both

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positive [6] and negative effects on GDP growth [7, 8].
Rainfall is very important for national economies, especially those of agricultural-based countries. Thailand has a service-based economy and is upper-middle income country that is situated in the tropics with an annual rainfall of approximately 1,400 mm [9]. The majority of existing studies have investigated the economic impacts of rainfall on low-income, agricultural-based economies [10, 11], especially in African countries facing arid and semi-arid conditions, with yearly rainfall of only about 700 mm [12], which differ greatly from Thailand. Moreover, the previous studies have typically focused on yearly precipitation data. The present study breaks down the analysis per season in order to provide a better understanding of the contribution of rainfall to economic growth in Thailand. Thus, the present study differs from the existing literature concerning the country's income level, economic characteristics, and volume of rainfall. The researchers' core assumption is that rainfall may affect the Thai economy differently compared to the agriculture-based economies that have been previously explored in depth in the existing literature.
In this research, a set of panel data was utilised in order to examine the impacts of seasonal rainfall on the rate of gross provincial product (GPP) growth across provinces and regions. The estimates suggest that, in the southern region, summer rainfall decreases the growth rate, while rainfall in the rainy season increases the growth rate. Meanwhile, the central region and the Bangkok Metropolitan Region continue to experience the positive effects of the rainfall in the summer. Thus, the impacts of the summer season are dominant. These results suggest that rainfall events, such as rainy season rainfall and summer rainfall, have the potential to increase the levels of economic inequality within the country.

## 2. Data

This study used the monthly precipitation and annual temperature data collected from 129 weather stations between 1995 and 2011 by the Thai Meteorological Department [13], which is the official organisation responsible for providing meteorological data in Thailand. Average annual rainfall (millimetres), divided by 100 for scaling purposes, and annual temperature (Celsius) were used and calculated using the average monthly data. The seasonal rainfall is divided into three seasons, which are the rainy season (June - October), winter (November - February) and summer (March - May), according to the Thai Meteorological Department. The provincial level GDP data was taken from the real GDP by province (also known as the gross provincial product [GPP] in Thailand), using chain volume measures against the reference year 2002, which was corrected by the Office of the National Economic and Social Development Board of Thailand [14], which is the official organisation responsible for providing economic data in Thailand. This data set was reported in an annual series in Thai baht, and the research used real GPP per capita growth. The population data was collected from the Department of Provincial Administration [15]. The data set was reported in an annual series, and the research used the population growth rate in this annual series.

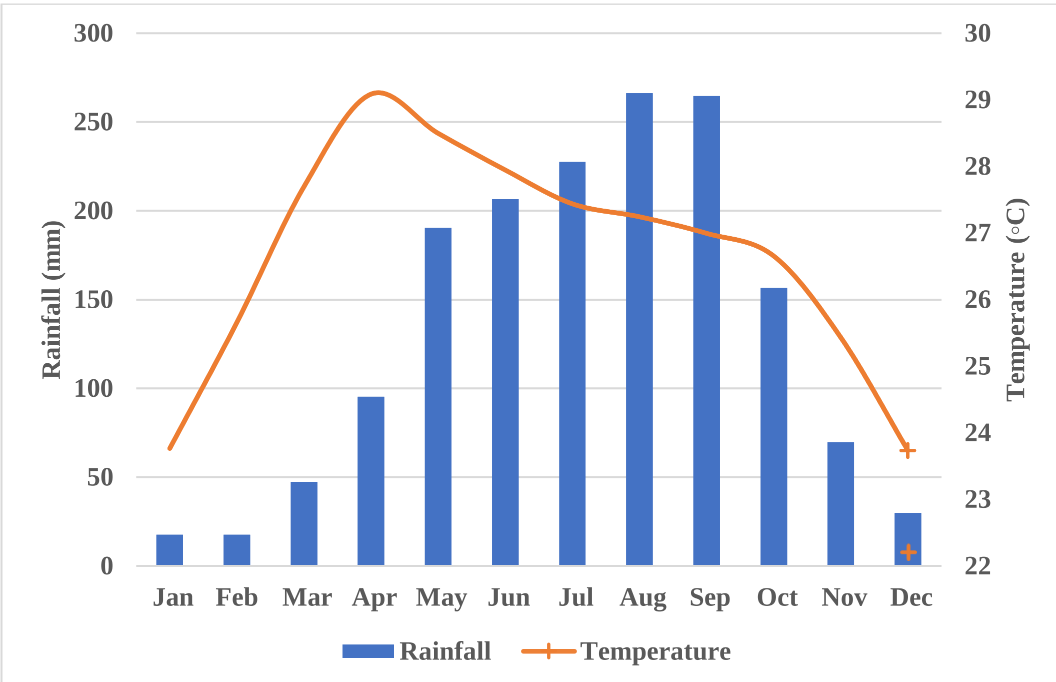


**Figure 1. Average monthly rainfall and temperature of Thailand for 1995-2015**

**Table 1: Summary statistics of the variables**

| Region | Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| Whole country | GPP per capita growth | 1596 | 0.023 | 0.067 | -0.39 | 0.43 |
| | Annual average rainfall (100 mm/year) | 1596 | 1.294 | 0.666 | 0.29 | 5.39 |
| | Annual average temperature (°C) | 1596 | 27.471 | 1.037 | 21.06 | 29.60 |
| | Population growth rate | 1596 | 0.006 | 0.012 | -0.06 | 0.15 |
| Northeastern | GPP per capita growth | 399 | 0.031 | 0.052 | -0.15 | 0.29 |
| | Annual average rainfall (100 mm/year) | 399 | 1.197 | 0.318 | 0.49 | 2.50 |
| | Annual average temperature (°C) | 399 | 26.830 | 1.032 | 21.06 | 28.80 |
| | Population growth rate | 399 | 0.003 | 0.006 | -0.03 | 0.03 |
| Northern | GPP per capita growth | 357 | 0.023 | 0.064 | -0.39 | 0.27 |
| | Annual average rainfall (100 mm/year) | 357 | 1.016 | 0.275 | 0.35 | 1.99 |
| | Annual average temperature (°C) | 357 | 26.918 | 1.116 | 24.30 | 29.10 |
| | Population growth rate | 357 | 0.001 | 0.015 | -0.06 | 0.15 |
| Southern | GPP per capita growth | 294 | 0.011 | 0.062 | -0.24 | 0.23 |
| | Annual average rainfall (100 mm/year) | 294 | 2.057 | 0.664 | 0.76 | 4.64 |
| | Annual average temperature (°C) | 294 | 27.559 | 0.485 | 26.00 | 29.10 |
| | Population growth rate | 294 | 0.011 | 0.011 | -0.04 | 0.08 |
| Eastern | GPP per capita growth | 168 | 0.035 | 0.087 | -0.24 | 0.43 |
| | Annual average rainfall (100 mm/year) | 168 | 1.733 | 1.040 | 0.71 | 5.39 |
| | Annual average temperature (°C) | 168 | 28.098 | 0.609 | 26.50 | 29.60 |
| | Population growth rate | 168 | 0.009 | 0.011 | -0.03 | 0.05 |
| Western | GPP per capita growth | 126 | 0.020 | 0.069 | -0.21 | 0.23 |
| | Annual average rainfall (100 mm/year) | 126 | 0.836 | 0.199 | 0.29 | 1.38 |
| | Annual average temperature (°C) | 126 | 28.104 | 0.465 | 27.10 | 29.20 |
| | Population growth rate | 126 | 0.004 | 0.009 | -0.04 | 0.04 |
| Central | GPP per capita growth | 126 | 0.020 | 0.077 | -0.16 | 0.23 |
| | Annual average rainfall (100 mm/year) | 126 | 0.839 | 0.247 | 0.30 | 1.52 |
| | Annual average temperature (°C) | 126 | 28.221 | 0.406 | 27.20 | 29.06 |
| | Population growth rate | 126 | 0.001 | 0.009 | -0.05 | 0.03 |
| Bangkok | GPP per capita growth | 126 | 0.016 | 0.077 | -0.38 | 0.21 |
| Metropolitan | Annual average rainfall (100 mm/year) | 126 | 0.936 | 0.330 | 0.29 | 1.89 |
| | Annual average temperature (°C) | 126 | 28.643 | 0.514 | 27.20 | 29.60 |
| | Population growth rate | 126 | 0.018 | 0.014 | -0.04 | 0.08 |
| Note: GPP per capita growth is in natural logs. | | | | | | |

Table 1 shows the GPP per capita growth rate from the previous year, annual average rainfall (mm), annual average temperature (°C) and the population growth rate from the previous year for the whole sample and by region. Table 1 shows that average rainfall varies across the regions in Thailand and that the southern region has the highest levels of rainfall, while the western region has the lowest.

## 3. Methodology

This research follows the methodology of Colacito, Hoffmann [16] and uses a fixed effects model to analyse the panel data so as to examine the impact of rainfall on GPP growth rate by region. Consider the equation:

$$\triangle y_{i,t} = \beta_1 rain_{i,t} + \beta_2 temp_{i,t} + \beta_3 pop_{i,t} + \alpha_i + a_t + \varepsilon_{i,t} \quad (1)$$

where $\triangle y_{i,t}$ is the GPP growth rate of province $i$ in year $t$, $rain_{i,t}$ is the average annual rainfall, $temp_{i,t}$ is the average annual temperature, $pop_{i,t}$ is the population growth rate, $\alpha_i$ is province fixed effects, $a_t$ is year fixed effects, and $\varepsilon_{i,t}$ is an error term. The present study added temperature to the estimated model for a robustness check since the rainfall variable may correlate with temperature [17]. Moreover, many researches have used population growth as a control variable in the field of climate change [18, 19]. Here, population growth and temperature are also used as control variables.

The model was adjusted to investigate the impact of seasonal variations on GPP growth rates. First, Equation 1 was redefined by dividing the total rainfall factor into three seasonal factors, to produce:

$$\triangle y_{i,t} = \sum_{s=1}^{3} \beta_s \, rain_{s,i,t} + \beta_2 temp_{i,t} + \beta_3 pop_{i,t} + \alpha_i + a_t + \varepsilon_{i,t} \quad (2)$$

where $rain_{s,i,t}$ is the average annual rainfall during the seasons: rainy, summer or winter.

We then differ from Colacito, Hoffmann [16] and develop two additional models with region to obtain:

$$\triangle y_{i,t} = \sum_{r=1}^{7} \beta_r \, rain_{i,t} + \beta_2 temp_{i,t} + \beta_3 pop_{i,t} + \alpha_i + a_t + \varepsilon_{i,t} \quad (3)$$

Finally, Equation 4 includes region and seasonal rainfall.

$$\triangle y_{i,t} = \sum_{r=1}^{7} \sum_{s=1}^{3} \beta_{r,s} \, rain_{s,i,t} + \beta_2 temp_{i,t} + \beta_3 pop_{i,t} + \alpha_i + a_t + \varepsilon_{i,t} \quad (4)$$

## 4. Results

Table 2 presents only the estimated coefficients of rainfall for each model, which are shown in order to highlight the differences across seasons and regions. The equation used to obtain each estimated coefficient is specified by the superscript to the upper right of each coefficient.

The estimates of Equation 1 suggest that average annual rainfall has a significant negative impact on GPP growth. The results of Equation 2 indicate that rainfall in the rainy season has the opposite effect on economic growth and that an increase in the annual average rainfall in summer and winter negatively affects the growth rate of GPP significantly. These results are consistent with the findings using data from Brazil [8], while an increase rainfall in the rainy season has a positive effect on this growth rate, although it is not significant. The differing positive and negative of these two effects suggest that previous studies' aggregation of rainfall data into annual rainfall averages [4, 20] may disguise the heterogeneous effects of the various seasons. The results of Equation 3 show that there is no significant impact of rainfall on economic growth across the seven regions.

When both regions and seasonal precipitation levels have been considered in Equation 4, the results suggest the following. Firstly, rainfall in the rainy season increases growth while rainfall in the summer decreases growth in the southern region. Precipitation can drive the southern economy in the rainy season since southern Thailand is a major tourist destination because this region includes numerous beaches and islands. Several economic activities are related to tourism such as hotels and restaurants, which has a 15 percent share of GRP, and transport, which has a 10 percent share of GRP in this region. This evidence shows that the proportion of tourism activities is rather high (see Appendix A1). Moreover, there are many tourist activities in the rainy season such as rafting, trekking, etc. In the summer, rainfall has a negative effect on economic outcomes, possibly due to the summer period of February to April being in the monsoon period, which is the season when it is not safe for travelling and fishing. Secondly, rainfall in the summer increases growth in the central region and the Bangkok Metropolitan Region. The major income of the central region comes from the industrial sector, contributing 65 percent of GRP, while the major income of the Bangkok Metropolitan Region comes from the service sector (see Appendix A1). Our hypothesis is that rainfall in the summer will increase labour productivity with regard to factory workers and officers in the service sector. The volume of rainfall in the summer is rather low with light rain; thus, it may not be an obstacle for commuting to work. Moreover, this evidence is consistent with Lee, Gino [21], who found that good weather can distract officers in a mid-size bank in Japan, whereas the bad weather increases individual productivity by eliminating potential cognitive distractions resulting from fine weather. In addition, bad weather conditions discourage customers from going out [22, 23]. Thus, e-commerce in the Bangkok Metropolitan Region can stimulate economic outcomes in this area. E-commerce is related to transportation according to Steinker et al. [24], who specified that to be efficient, logistics

operations in e-commerce require warehousing and transportation resources so as to be aligned with sales. They reported that rain had a positive effect on online sales. This evidence indicates that these two activities, e-commerce and transportation, can drive the service industry growth in the Bangkok Metropolitan Region.
Overall the results we found that controlling for these two additional sets of control variables, temperature and population growth rate, does not alter our main conclusions regarding the effect of seasonal precipitation on GPP growth.

**Table 2: Panel data model. Sample: 76 provinces, 7 regions, 1995-2015; Estimation method: Fixed effect model**

| | **Whole year** | **Rainy** | **Summer** | **Winter** |
|---|---|---|---|---|
| Whole country | -0.0122*[1] | 0.00249[2] | -0.0193***[2] | -0.00882**[2] |
| | (0.0065) | (0.0033) | (0.0048) | (0.0043) |
| 1. Northeastern | 0.0109[3] | 0.00473[4] | 0.00756[4] | 0.0101[4] |
| | (0.0111) | (0.0051) | (0.0107) | (0.0148) |
| 2. Northern | 0.0134[3] | 0.000786[4] | 0.0118[4] | 0.0170[4] |
| | (0.0167) | (0.0084) | (0.0171) | (0.0183) |
| 3. Southern | -0.00944[3] | 0.0148*[4] | -0.0382***[4] | -0.00188[4] |
| | (0.0124) | (0.0077) | (0.0082) | (0.0057) |
| 4. Eastern | 0.0102[3] | 0.00266[4] | 0.0125[4] | 0.00201[4] |
| | (0.0224) | (0.0106) | (0.0237) | (0.0248) |
| 5. Western | -0.00499[3] | 0.0132[4] | -0.0239[4] | -0.00609[4] |
| | (0.0367) | (0.0219) | (0.0250) | (0.0197) |
| 6. Central | -0.0179[3] | -0.0305[4] | 0.0706*[4] | -0.0180[4] |
| | (0.0388) | (0.0221) | (0.0391) | (0.0394) |
| 7. Bangkok Metropolitan | -0.0208 [3] | -0.00925[4] | 0.0572*[4] | -0.0547[4] |
| | (0.0379) | (0.0220) | (0.0341) | (0.0351) |

Notes:
1. Standard errors in parentheses
2.*Significant at 10%, **Significant at 5%, ***Significant at 0.1%
3. The results are consistent with the fixed effects within estimator. Full regression estimates are available upon request.

## 5. Discussion and future work

This research proposes that the economic growth in the seven regions of Thailand is impacted differently by the seasonal precipitation levels. Rainfall in summer has an impact on economic growth in many of the regions, the most significant impact being in the southern and central regions, as well as the Bangkok Metropolitan Region, while the rainfall in the rainy season has a major effect on economic growth in only the southern region. Adding to the growing body of literature, our analysis suggests that certain volumes of rainfall events caused by climate change, consequently, have the potential to influence the economic growth inequality within Thailand. This finding can help to determine where aid is most needed and which areas may become more vulnerable because of rainfall. Future work could extend the analysis presented in this study by investigating the extreme rainfall events such as drought or flooding.

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# Appendix A

## Table A1 Share of Gross Regional Product by subsector in 1995 and 2015 across 7 regions

| Region | Year | Agriculture | | Industry | | | | Services | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Farming | Fishing | Mining | Manufacturing | Electricity | Construction | Wholesale | Hotels | Transport | Financial | Realestate | Public | Education | Health and social work | Other | Private | total |
| 1. NORTHEASTERN | 1995 | 16.88 | 0.60 | 1.29 | 15.04 | 1.76 | 10.96 | 13.35 | 2.07 | 3.98 | 6.01 | 4.77 | 7.78 | 11.88 | 2.15 | 1.75 | 0.53 | 100 |
| | 2015 | 16.05 | 0.41 | 0.92 | 20.72 | 2.54 | 5.01 | 11.66 | 1.49 | 3.74 | 7.38 | 6.98 | 5.60 | 11.76 | 3.26 | 1.52 | 0.36 | 100 |
| 2. NORTHERN | 1995 | 16.40 | 0.55 | 5.16 | 14.23 | 2.14 | 8.67 | 13.73 | 2.18 | 4.94 | 6.60 | 4.99 | 7.98 | 8.66 | 2.58 | 1.18 | 0.48 | 100 |
| | 2015 | 15.53 | 0.49 | 4.18 | 16.65 | 3.17 | 5.30 | 12.54 | 3.38 | 4.56 | 7.27 | 7.26 | 5.94 | 8.33 | 4.17 | 1.31 | 0.33 | 100 |
| 3. SOUTHERN | 1995 | 15.19 | 13.97 | 2.11 | 12.63 | 1.90 | 6.12 | 15.12 | 3.54 | 4.72 | 4.82 | 2.90 | 10.15 | 5.00 | 1.25 | 1.35 | 0.17 | 100 |
| | 2015 | 13.19 | 7.43 | 4.56 | 9.89 | 2.89 | 3.81 | 9.28 | 15.73 | 10.28 | 4.91 | 5.27 | 5.13 | 5.42 | 2.41 | 1.26 | 0.10 | 100 |
| 4. EASTERN | 1995 | 7.22 | 2.83 | 6.23 | 46.98 | 3.70 | 3.23 | 13.84 | 2.10 | 3.16 | 2.88 | 1.56 | 2.64 | 1.50 | 0.53 | 0.50 | 0.11 | 100 |
| | 2015 | 4.71 | 1.15 | 10.08 | 48.88 | 6.46 | 2.11 | 8.95 | 2.24 | 4.36 | 2.07 | 4.76 | 2.26 | 1.20 | 0.90 | 0.38 | 0.05 | 100 |
| 5. WESTERN | 1995 | 14.58 | 3.17 | 3.77 | 25.68 | 2.65 | 6.64 | 14.16 | 1.90 | 5.48 | 5.77 | 3.41 | 6.89 | 4.33 | 1.51 | 1.34 | 0.28 | 100 |
| | 2015 | 12.90 | 2.19 | 2.47 | 25.05 | 10.96 | 4.17 | 9.43 | 4.11 | 4.91 | 4.63 | 5.40 | 5.25 | 4.71 | 2.60 | 1.06 | 0.31 | 100 |
| 6. CENTRAL | 1995 | 6.31 | 0.27 | 3.85 | 48.90 | 3.23 | 4.16 | 14.93 | 0.52 | 2.91 | 3.72 | 2.45 | 4.64 | 2.68 | 1.00 | 0.57 | 0.12 | 100 |
| | 2015 | 3.69 | 0.13 | 1.17 | 62.48 | 3.62 | 1.54 | 8.48 | 0.57 | 3.86 | 2.50 | 5.59 | 3.28 | 1.95 | 1.40 | 0.53 | 0.09 | 100 |
| 7. BANGKOK AND VICINITIES | 1995 | 0.43 | 0.53 | 0.03 | 25.64 | 2.12 | 8.07 | 23.52 | 4.79 | 8.02 | 14.04 | 5.28 | 2.79 | 1.54 | 0.99 | 3.54 | 0.45 | 100 |
| | 2015 | 0.35 | 0.41 | 0.04 | 23.22 | 1.79 | 2.20 | 18.88 | 5.94 | 14.40 | 9.25 | 10.28 | 6.42 | 1.61 | 1.84 | 2.98 | 0.19 | 100 |

Source: Authors' calculation by using the information from the National Account of Thailand [14]