Research Paper

Evaluation of Economic Damage Caused by Drought in Central Region Vietnam: A Case Study of Phu Yen Province

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Research Highlights

- Research on economic damage caused by drought in Central Vietnam
- Short-term and long-term effects of drought on manufacturing industries and domestic trade
- Contributing to proposing solutions for drought management in the context of climate change in Vietnam

ABSTRACT

This paper aims to study the impact of natural disasters on per capita income in Vietnam both the short and long-term, specifically impact loss of income caused by the extreme drought 2013 for agriculture, forestry and fishery in Phu Yen Province, Central Vietnam. The study valued economic damage by applying the synthetic control method (SCM), which is a statistical method to evaluate the effect of an intervention (e.g. natural disasters) in different case studies. It estimates what would have happened to the treatment group if it had not received the treatment by constructing a weighted combination of control units (e.g. control provinces). The results showed that the 2013 drought caused a decrease in income per capita, mainly in the agriculture, forestry, and fishery sector in Phu Yen. The reduced income was estimated to be VND 160,000 (1 USD = 23,500 VND (2021)) for one person per month, accounting for 11% of total income per capita and continued to affect the income 6 years later. Therefore, authorities need to invest in preventive solutions such as early and accurate warnings to help people to be more proactive in disaster prevention.

Keywords : Synthetic control method, drought, economic damage, Phu Yen province

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1. Introduction

Climate change is projected to create new hazards such as glacier melting, sea level rise and extreme weather events in proportions never seen before (Bosello *et al.*, 2012). This will aggravate the existing disaster risks and vulnerabilities and expose millions of people never affected before around the world. Large and sudden disasters often have serious consequences compared to cyclical ones. The number of natural disasters, especially hydrometeorological disasters has been on the rise in recent years (Estrada *et al.*, 2015). The loss and damages caused by natural disasters are expected to rise further in future largely due to climate change and the increased disaster exposure and vulnerability of our modern societies (Dietz 2011; Intergovernmental Panel on Climate Change - IPCC 2012, 2014). Disasters caused by hydrometeorological events such as tropical cyclones, floods, landslides, and droughts have affected most countries in the South East Asia region (Pauw *et al.*, 2012; Samphantharak 2019). Understanding the economic impact of natural disasters on local economy is critically important since it provides inputs for decision makers in the design and implementation of disaster risk management solutions. Economic policymakers need to estimate and forecast the economic impacts of disasters, differentiating disaster-driven economic fluctuations from other sources (Tran and Wilson 2020).

To mitigate the damage caused by natural disasters, scientists have developed many methods and models to predict natural disasters before they occur and help people to be more proactive in coping with natural disasters (Okuyama *et al.*, 2004; Cavallo and Noy 2011; Loayza *et al.*, 2012; Ackerman and Munitz 2012; Fomby *et al.*, 2013; Fan *et al.*, 2018; Botzen *et al.*, 2019; Fatouros and Sun 2020). However, studies on the impact of natural disasters on economic variables have not been conducted much, especially those for an individual country (Loayza *et al.*, 2012; Ahlerup 2013; Guo *et al.*, 2015). In Vietnam, studies on the impact of natural disasters on the economy are mainly short-term (Ilan and Vu 2009; Le 2013; Im and Vu 2013) and long-term studies have not been conducted much.

This study applies the Synthetic Control Method (SCM) to estimate the economic damage caused by the extreme

drought in 2013 in Phu Yen Province, Central Vietnam. SCM is a statistical method used to evaluate the effect of an intervention in comparative case studies by constructing a weighted combination of control groups, to which the treatment group is compared. This comparison is used to estimate what would have happened to the treatment group if it had not received the treatment. The drought in Phu Yen 2013 is chosen for the case study because it caused great damage in the Central region in the past 10 years. Additionally, it is appropriate time to apply SCM since it requires a pre-drought data series and a post-drought data series. The results of the damage valuation can inform decision makers in the design and implementation of solutions to prevent and increase community resilience to disasters.

2. Materials and Methods

2.1. Description of study area

Phu Yen Province is located in the lower Ba River basin. It is the largest river in the central coastal region, flowing through four central provinces of Viet Nam including Kon Tum, Gia Lai, Dak Lak and Phu Yen with an area 13,900 km² (Fig. 1a). In 2013, it was the heaviest drought event in the period 2005-2016 in Phu Yen Province. Many areas in Phu Yen Province did not have rainfall in the first 6 months of the year. According to the Provincial Irrigation Sub-Department, in nearly 25,000 hectares of summer-autumn rice, over 1,300 hectares in total had been lost. There were also 5,000 hectares of rice waiting to die (<http://thongkephuyen.gov.vn/>). All irrigation reservoirs in this province were below the dead water level. Two reservoir systems of Ba Ha and Song Hinh were used to supply water for the downstream area but water level in the rivers and streams in Phu Yen were dry, leading to a serious shortage of domestic water. According to Department of Agriculture and Rural Development (DARD) Phu Yen's statistics, over 35,000 people in more than 10,200 households suffered from severe water shortage for their daily life. Dong Xuan, Son Hoa, Tuy Hoa, and Song Cau districts were severely affected. This province's historic drought has also led to an unprecedented wildfire disaster. Only in the first three months of the year, there were 66 forest fires

Fig. 1a. Ba River basin, Phu Yen Province.

in the area, burning 1,200 hectares (<http://sonongnghieppy.gov.vn/Home/List/29>). In addition, there were over 2,400 hectares of burned plantation forest.

2.2. Synthetic control method and data collection

2.2.1. Economic model of synthetic control method

According to the Center for Research on the Epidemiology of Disasters (CRED) (2020) (<https://www.cred.be/>), a natural disaster is defined as a natural event that is out of local control and requires external assistance. Also, according to CRED, a natural disaster is recorded when one of the following 4 conditions is established: (1) More than 10 deaths are reported; (2) More than 100 people are affected; (3) A state of emergency is declared; and (4) Call for external assistance is settled.

This study adopted the SCM model which have been applied in previous studies for disaster damage valuation (Abadie 2021; Albalade and Padró 2018; Cavallo *et al.*, 2013; Sills and Herrera 2015). For SCM model, provinces are divided into two groups: the control group and the treatment group. The control group includes provinces that are not affected by drought and the treatment group is

affected provinces by a drought (represented by Phu Yen Province). The specific model and estimation are described as follow:

Suppose that J is the number of provinces in control group. Thus, there are $J+1$ provinces in the dataset (including 1 province in treatment group). Call Y_{it}^N is per capita income of province i at the time t if not being affected by the drought and Y_{it} is per capita income of province i at the time t in case being affected by the drought 2013. For provinces $i = 1, J+1$ and $t = 1, T$ with T_0 is time the drought occurred ($1 < T_0 < T$). So, we have $Y_{it}^N = Y_{it}$ for years before the drought occurred.

For years after the occurrence of the drought, let $\alpha_{it} = Y_{it} - Y_{it}^N$ representing impacts of the drought on province i at time t , ($t = T_0 + 1, T_0 + 2, \dots, T$). The objective of the study is to compare the per capita income of the province affected by the drought with other unaffected provinces. Therefore, we have to estimate:

$$\alpha_{it} = Y_{it} - Y_{it}^N \quad \text{with } t > T_0 \quad \text{Eq. (1)}$$

Data about Y_{it} is available, thus estimation of α_{it} requires Y_{it}^N . However, there are no data of Y_{it}^N . SCM will estimate this parameter through the control group, or Y_{it}^N is estimated as average weights of Y_{jt} (per capita income of the control group) where $j = 2, J+1$ or Y_{it}^N could be estimated as follow:

$$Y_{it}^N = \sum_{j=2}^{J+1} w_j Y_{jt} \quad \text{Eq. (2)}$$

with $w_j \geq 0$ (w_j is the weight for the control provinces).

The estimation of w_j as follow (Abadie 2010):

$$W = (w_2^*, \dots, w_{J+1}^*) \text{ that minimizes } \|X_1 - X_0 W\|_V = \sqrt{(X_1 - X_0 W)' V (X_1 - X_0 W)} \quad \text{Eq. (3)}$$

subject to the restriction that $w_2, \dots, w_{J+1}$ are nonnegative and sum to one.

$$\text{with } X_1 = \begin{bmatrix} X_{11} \\ X_{12} \\ \vdots \\ X_{1K} \end{bmatrix} \quad X_0 = \begin{bmatrix} X_{21} & X_{31} & \dots & X_{J+1,1} \\ X_{22} & X_{32} & \dots & X_{J+1,2} \\ \vdots & \vdots & \ddots & \vdots \\ X_{2K} & X_{3K} & \dots & X_{J+1,K} \end{bmatrix} \quad \text{Eq. (4)}$$

where W is the matrix ($J \times 1$) that contains the weights

of the provinces in the control group, X_1 is the matrix ($K \times 1$) contains explanatory variables for per capita income of Phu Yen. X_0 is the matrix ($K \times J$) contains explanatory variables for per capita income of provinces in the control group. In the treatment province, there are similar explanatory variables.

Hence, $(X_1 - X_0W)$ is the difference between the treatment and control groups for explanatory variables. The SCM estimates the weights by minimizing the difference between Phu Yen province and the control group at the period of time before the drought occurs. The estimation of w_j will help to identify provinces in the control group that are similar to Phu Yen in terms of income and other social and economic factors (Table 1).

Once the weighting of the SCM has been determined for the pre - drought period, it is used to construct a counterfactual trend for the economic variables in the post-drought period. The difference between this counterfactual trend and the actual trend for the treated unit (Phu Yen) represents the estimated drought effect.

2.2.2. Statistical significance testing

In this case study, if the drought has an impact on reducing per capita income, it is able to estimate that the value of $\hat{\alpha}_{1t} = Y_{1t}^J - \hat{Y}_{1t}^N$ is negative because per capita income in Phu Yen is less than the per capita income of control group. However, to test if this estimate is really negative or due to bias in data collection and processing, it is necessary to test $\hat{\alpha}_{1t}$. Based on research by Abadie *et al.* (2010, 2015), Abadie and L'Hour (2020), Cavallo *et al.* (2013), $\hat{\alpha}_{1t}$ will be tested by permutation test. This test is also called the Placebo test. In the permutation test,

Table 1. List of 29 provinces in control group

North region	Central region	South region	
Bac Can	Dac Lac	Bac Lieu	Tay Ninh
Bac Ninh	Gia Lai	Binh Duong	Tien Giang
Dien Bien	Binh Thuan	Binh Phuoc	Tra Vinh
Hai Duong		Ca Mau	Ho Chi Minh City
Ha Nam		Dong Nai	Vinh Long
Hoa Binh		Dong Thap	
Hung Yen		Hau Giang	
Thai Nguyen		Kien Giang	
Tuyen Quang		Long An	
Phu Tho		Soc Trang	

estimating the change in income of unaffected provinces is by using SCM as for affected provinces. The p_value will be calculated as follows:

$$p_value_t = \Pr(\hat{\alpha}_{j,t}^{PL(j)} \leq \hat{\alpha}_{1,t}) \text{ with } j = \overline{1, J+1} \quad \text{Eq. (5)}$$

where p_value is the probability that the impact of the extreme drought in Phu Yen is less than that on the provinces in control group. In which $\hat{\alpha}_{j,t}^{PL(j)}$ is the estimated value of the income change of the control group.

2.2.3. Methods for identifying control groups

In the comparison, it is necessary to determine a control group to compare with a treatment group. The results are only meaningful when the control group is not affected by natural disasters and the treatment group is affected. However, among 63 provinces and cities (total in Vietnam), none of the provinces was not affected by the drought 2013. Furthermore, the impact of natural disasters on provinces varies in the extent of damage (number of deaths, destroyed houses). Therefore, the control group is defined again as

Fig. 1b. Provinces, Cities, Capital in Vietnam.

a group that is not affected by the “major disaster”. So, to what extent of damage that a natural disaster is called “major disaster”.

According to Le (2013), “major disasters” are defined as 25% of the biggest recorded natural disasters or those with more than 5 deaths per million people and over 275 houses destroyed per million people. Therefore, the control group is the provinces that were neither affected by this drought nor any “major disaster” during the study period. Twenty-nine (29) provinces met the conditions of being the control group (Table 1, Fig. 1b).

2.3. Data collection

The research collected natural disaster and economic data during 2000-2019. Natural disaster data is applied to build the control group while economic data is to estimate the impact of disasters on per capita income. Disaster data was collected from the database “Disaster Information Management System” (www.desinventar.net) of the United Nations Office of Disaster Risk Reduction. This database provides information regarding disasters for all nations and regions including Vietnam. To test whether the control

group is economically affected by major natural disasters after 2013, the dataset from CRED (2020) recording the losses caused by natural disasters from 1953 to the present is used. This dataset contains information in a provincial level.

Data on per capita income was collected from the General Statistics Office (GSO) for the period of 2009-2019 and variables are denoted in Table 2. The explanatory variables for per capita income were chosen based on recent empirical research on income (Vu and Im 2011). They are Sales Retail per capita (SALES) as a proxy for domestic trade, goods transported (INFR) representing infrastructure, capital for provinces (CAP), number of doctors per capita (DOCTOR) representing health care, the number of pupils per capita (STUDENT) representing education, and land per capita (LAND).

3. Results and Discussion

3.1. Impact of the extreme drought on the per capital income of Phu Yen

From the available dataset, SCM was applied to assess the impact of drought on per capita income. The independent

Table 2. Mean of the variables in the period 2009-2019

Variables	Explanation	Unit	Before drought (2009-2013)		After drought (2019-2019)	
			Phu Yen	Control group	Phu Yen	Control group
Dependent variables						
INCOME	Per capita income	VND thousand/ month	2331.25	2523.25	3396.60	3756.05
S_INCOME	Income from salary	VND thousand/ month	192.43	206.74	284.97	373.83
AFF_INCOME	Income from agricultural, forestry and fishery	VND thousand/ month	242.73	240.11	317.74	309.92
NAFF_INCOME	Income from industry, construction, trade and service	VND thousand/ month	130.18	153.09	221.42	234.98
Explanatory variables						
SALES	Sale retail per capita	VND million/ person/ year	5.19	6.80	9.79	12.04
INFR	Goods transported	Ton×km/ person/ year	0.26	0.43	0.39	0.69
DOCTOR	Number of doctor per capita	Number of doctors/ 1000 people	2.48	2.46	2.57	2.68
CAP	Capita for provinces	VND million/ person/ year	3.87	17.67	5.55	32.10
STUDENT	Number of pupils per capita	Number of students/ 1000 people	96.26	114.16	82.59	96.05
LAND	Land per capita	Km ² / 1000 people	2.67	6.51	2.71	6.15
RICE	Annual rice yield	Ton/ person/ year	0.41	0.94	0.41	1.06
NUTTREE	Annual grain yield	Ton/ person/year	0.42	1.01	0.41	1.16
WOOD	Annual timber production	M ³ / person/ year	0.01	0.07	0.00	0.08
FISH	Annual aquaculture production	Ton/ 1000 people/ year	153.37	83.43	316.01	132.16

variables were selected including SALES, INFR, CAP, DOCTOR, STUDENT, and LAND. To minimize the gap between the treatment and control groups, the weights of provinces are estimated in details in Table 3. It is able to estimate the per capita income of Phu Yen province if there was no occurrence of drought 2013 by comparing the estimated income value and the actual income value of Phu Yen.

Fig. 2 shows the actual income trend of Phu Yen (dashed line) and the control group (solid line). The detailed analysis shows that the drought reduced the per capita income of Phu Yen in the period 2013-2019 by VND 160,000. These results had statistical significance of less than 10% for the period 2013-2015 while other years had no statistical significance. In other words, in the short term, the 2013 drought caused a decrease in per capita

Table 3. Weights of provinces in the control group

Province	Weight	Province	Weight
An Giang	0	Hau Giang	0
Bac Can	0	Hoa Binh	0
Bac Lieu	0	Hung Yen	0
Bac Ninh	0	Kien Giang	0
Binh Duong	0.286	Long An	0
Binh Phuoc	0	Phu Tho	0
Binh Thuan	0	Soc Trang	0
Ca Mau	0	Tay Ninh	0
Dac Lac	0	Thai Nguyen	0
Dien Bien	0.506	Tien Giang	0
Dong Nai	0	Ho Chi Minh	0
Dong Thap	0	Tra Vinh	0
Gia Lai	0	Tuyen Quang	0
Hai Duong	0	Vinh Long	0.242
Ha Nam	0

Fig. 2. Phu Yen's per capita income trend compared to the control group.

income in Phu Yen, but in the long term, the drought had no impact on per capita income.

3.1.1. Permutation test for research results

The reliability of the research results is very important. Based on research by Abadie *et al.* (2010), the researcher used permutation tests to test the reliability of results. In this case, the decrease of Phu Yen's per capita income was tested whether it was affected by drought. Fig. 3 shows all income gaps of permutation testing and Fig. 4 shows the p-value for periods.

Fig. 3. Change of income in Phu Yen compared to the control group.

Fig. 4. The significance of permutation test on income of Phu Yen.

3.2. Impact of the extreme drought on different per capita income

The GSO report on per capita income for provinces and cities was divided into smaller categories: income from salary, income from agriculture, forestry and fishery, income from industry, construction, trade, services, and income from other sources. In order to get more specific policy recommendations, the impact of drought on these income components was analyzed in more detailed.

3.2.1. Impact of the drought on income from agriculture, forestry and fishery

When analyzing the impact of drought 2013 on income from agriculture, forestry, and fishery (AFF-income) and in order to increase the reliability of the research results, the study included the following explanatory variables: Annual rice yield (RICE), annual grain yield (NUTTREE), annual timber production (WOOD) and annual aquaculture production (FISH) (Table 2). The analysis showed that the drought reduced the per capita income from agriculture, forestry, and fishery by an average of VND 220,000 per month, accounting for 11% of the average income of local people in Phu Yen. Fig. 5a shows the trends of income from agriculture, forestry and fishery of Phu Yen and the control group.

Permutation test shows that the above results are statistically significant at 10% in 2013 and 2014, 5% in 2015, 2016, 2017, and 2018 (Fig. 4). From the above results, it is confirmed that in the long term, the drought impacts reduced incomes from agriculture, forestry, and fishery of people in Phu Yen.

3.2.2. Impact of the drought on income from salary

For income from salary, the selection of explanatory variables (SALES, INFR, CAP, DOCTOR and STUDENT) was similar to the income analysis. After analysis using synthetic control methods, the results show that this drought reduced income from salary. However, the results were not statistically significant after permutation tests. Fig. 5c shows the trend of Phu Yen's income from salary compared to the control group.

3.2.3. Impact of the drought on income from industry, construction, trade and services

When analyzing the impact of this drought on income

Fig. 5a. Trend of income from agriculture, forestry and fishery of Phu Yen and control group.

Fig. 5b. Agriculture, forestry, and fishery income changes of Phu Yen and control group.

Fig. 5c. Trends of income from salary of Phu Yen and control group.

from industry, construction, trade, and services, the same control variables of the income from salary was selected (SALES, INFR, CAP, DOCTOR and STUDENT). After

Fig. 5d. Trends of income from industry, construction, trade and services of Phu Yen and control group.

applying SCM, the trend analysis shows that drought increased the income from industry, construction, trade, and services (Fig. 5d). However, the results were also not statistically significant after permutation tests. This can be explained by the fact that reconstruction has been done after the disaster. Therefore, people's income from these activities would be increased but only existed a few years after the drought occurred.

4. Conclusions and Recommendations

In this study, the SCM is applied for comparison of the control and the treatment groups to understand the effect of an extreme drought on per capita income in Vietnam. The treatment group was Phu Yen Province and 29 provinces selected from 63 provinces in Vietnam was included in the control group. The results showed that the drought reduced short-term per capita income. The decrease in per capita income caused by drought was estimated at VND 160,000 per month. This impact only existed within 3 years after the disaster occurred. When analyzing the components of income in more details, this extreme drought had no impact on income from wages nor income from industry, construction, trade, and services. However, it reduced the income from agriculture, forestry, and fishery in the long term. Per capita income from agriculture, forestry, and fishery due to the drought 2013 was reduced at VND 220,000 per month, equivalent to 11% of the per capita income of Phu Yen and lasted up to 6 years after it occurred.

Therefore, the drought has a major impact on people whose income are mainly from agriculture, forests, and aquaculture. Therefore, policy makers and relief organizations should prioritize the affected people from agriculture,

forestry, and fishery to avoid inefficient and unfair relief operations. Relief activities should not stop at the year when a disaster occurs but should be extended up to several years after that. Communities do not prepare to prevent for a drought as they do not think the event will last longer than expected. Therefore, to reduce the damage caused by drought and other natural disasters, localities need to raise people's awareness by propagating the impacts of natural disasters and the measures to mitigate those impacts. Authorities need to provide early and accurate warnings to help people to be more proactive in disaster prevention.

Data Availability Statement

The data presented in this study are available in article.

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Conflicts of Interest

The author declare no conflict of interest.

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