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**LONG-TERM IMPACT OF NATURAL DISASTERS ON VIETNAMESE INCOME PER CAPITA:
THE CASE OF TYPHOON DURIAN***

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Abstract. This study estimates the effect of natural disasters on Vietnamese income per capita in both short and long-term. The analysis also evaluates the effects by sources of income including income from salary; income from agriculture, fishery, forest; and income from industry, construction, trade, and services. Typhoon Durian happened in December 2006 in southern provinces of Vietnam is chosen for the comparative case study. The analysis applies the Synthetic control method (SCM) to construct a counterfactual with respect to two different control groups and conducts a permutation test for the estimated values. The results show that typhoon Durian decreased aggregate income per capita of the affected region and the effect was long lasting. The reduction of monthly income per capita was estimated to be 56,925 VND which accounts for 7.9% of the total income. The most affected source of income is from agriculture, forestry, and fishery.

Keywords: typhoon; income per capita; synthetic control method

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JEL Classifications: E40, O11, Q54

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1. Introduction

Research on the impact of natural disasters often focus on the short-term, leaving much of the long-term impact unexplored (Noy and DuPont, 2018; Fakhry et al., 2018; Chehabeddine, Tvaronavičienė, 2020). One could speculate that in the short-term, farms destroyed by disasters have no harvesting, factories damaged by disasters have little output and hence a negative impact on output is inevitable. Speculation of long-term impacts of natural disasters is more complex. In the long-term, new crops will likely be planted on farms, damages at factories will likely be remedied and output will likely recover to equilibrium. Further, damage caused by natural disasters may enable better investment in new technology, and hence allow to achieve higher output in the long-term. Hence, long-term impacts of natural disasters can be positive, negative or neutral based on the post-disaster relief and post-disaster investments (Rempel, 2010).

Estimating a long-term impact of natural disasters is challenging, both empirically and theoretically. Theoretically, natural disasters do not have a clear-cut effect on output and economic growth over the long-term. Traditional neo-classical growth models predict that a negative capital shock following a natural disaster does not affect the rate of technological progress and therefore have little effect over the long-term growth. On the other hand, endogenous growth models based on creative destruction process argue that negative capital shocks may spur the process of reinvestment and upgrading of capital goods and thereby lead to higher growth (Caballero & Hammour, 1994; Cavallo et al., 2013; Heger & Neumayer, 2019). Endogenous growth models that assume increasing return to capital, however, predict a lower growth prospect. Empirically, to estimate the long-term effect, one must collect the data several years before disasters and several years after disasters. In some cases, data are not sufficiently available for making inference statistics. In addition, since there are many factors that can affect output in the long-term, it is difficult to separate the impact of disaster from the impact of other factors.

Most of existing empirical studies rely on household survey data to analyze the short-term impact of natural disasters. Whilst these studies differ with respect to the regions chosen as comparative case studies, the specific types of disasters and the methods used to estimate the impact of disasters, they largely find an income reducing effect of natural disasters for the short-term (Paxson, 1992; Thomas *et al.*, 2010; Coffman & Noy, 2012; Bui *et al.*, 2014; Arouri *et al.*, 2015; Gignoux and Menéndez, 2016; Karim, 2018; De Oliveira, 2019; Tselios & Tompkins, 2019). The negative impact of natural disasters on income is estimated ranging from 1.9% for the case of storms happening in Vietnam in the study of Arouri *et al.* (2015) to 23% for the case of floods happening in Vietnam in the study of Thomas *et al.* (2010).

From a policy perspective, long-term effects of natural disasters are as important as short-term effects (Lynham *et al.*, 2017). Yet, empirical evidence on the long-term effects of natural disasters on economic growth is scarce with a few exceptions that show different results (Xiao, 2011; Coffman and Noy, 2012; and Alwis and Noy, 2019; Parida et al., 2020). Xiao (2011) uses time-series analysis to estimate the impact of the 1993 Midwest flood and confirmed that Midwest flood had no impact on personal income but had a positive impact on agriculture in the long-term. Coffman and Noy (2012) apply the SCM to estimate the impact of Hurricane Iniki on Hawaii Island. Using data retrieved from a database maintained by the University of Hawaii Economic Research Organization (UHERO) for the period 1975-1991, the revealed findings suggest that aggregate personal income was 12% lower than the case the hurricane would have not occurred. Similarly, Parida et al. (2020) find a negative impact of flood on real per capita GSDP in Indian states. Different from previous two studies, Alwis and Noy (2019) find an increase in household income in Sri Lanka eight years after the 2004 Indian Ocean tsunami. Using the Difference in Difference method with data collected from five household survey in 1995, 2002, 2006, 2009, and 2012, Alwis and Noy (2019) attribute the positive effect of the tsunami to the large amount of external relief Sri Lanka received in the aftermath of the disaster.

Empirical studies of the impact of natural disasters on income for Vietnam are exclusively focused on the short-term impacts and only use household data retrieved from the Vietnam Household Living Standard Surveys (Thomas *et al.*, 2010; Bui *et al.*, 2014; Arouri *et al.*, 2015). These studies reach the same conclusion that natural

disasters have negative impacts on household income. Thomas *et al.* (2010) conclude that 23% of welfare decreases because of riverine flood and 52% of welfare decreases because of a hurricane affecting the cities which have more than 500,000 people. Bui *et al.* (2014) find a decline of 6.9% and 7.1% for Vietnamese household income and expenditure respectively due to natural disasters. They also find that income inequality and poverty are also affected by natural disasters. And lastly, Arouri *et al.* (2015) find that household income per capita decreases by 1.9% in the commune affected by storms.

The present study is a first attempt to investigate the effects of natural disasters on income per capita both in short-term and long-term for the case of Vietnam. Typhoon Dorian which occurred in 2006 in the southern provinces of Vietnam was chosen as the case study. Storms and typhoons are common in Vietnam as well as in other countries (CRED, 2018a). Hence, findings of this study provide relevant policy implications with respect to alleviation of the impact of natural disasters at both short- and long-term basis, for similar events like typhoon Dorian. Different from previous studies which are focused on the impact of natural disasters on aggregate income or total income, this paper investigates effects of typhoon Dorian by income source, including income from salary; income from agriculture, fishery, forest; and income from industry, construction, trade and services. This approach provides an insightful understanding of the types of households that are most prone to adverse effects of the typhoon. Policy implications drawn on findings of this study will therefore be more targeted and effective, whereby policymakers can prioritize disaster aids to households whose income is most affected by natural disasters, helping speed up the recovery process.

In this study, following Abadie and Gardeazabal (2003), Abadie *et al.* (2010), we use the SCM to construct a counterfactual and implement permutation test for the estimated values. The study provides several key contributions. First, it contributes to *limited* evidence of the long-term impact of natural disasters on income with an application of the SCM. It also extends the analysis of the impact of natural disasters on disaggregated sources of income rather than aggregate income per capita. The paper proceeds as follows. The next section presents an overview of Vietnam's economy and typhoon Dorian. Section 3 discusses the methodology of synthetic control which is followed by an empirical specification and relevant tests. Section 4 describes the data and presents an empirical analysis. Section 5 discusses the findings and the final section concludes the paper.

2. Vietnam and typhoon Dorian

Vietnam is located in tropical region with a long coastline of 3260 km, Vietnam is often affected by tropical storms in the coastline area and floods after storms because of rainfall (Desinventar, 2018). According to the report of CRED (2018b), Vietnam is one of the top ten countries affected by natural disasters. In 2017, natural disasters in Vietnam caused 316 deaths and 3.1 billion US\$ damage accounted for 1.4% of Vietnam's GDP. Vietnam Income per capita in PPP dollars from 2012-2014 is \$3771 with an average income growth rate of 6.5% (World Bank, 2018). Vietnam is still considered as lower middle-income country. In addition, according to GSO (2018), Vietnamese income from agriculture, forestry, and fishery accounts for 27.2% of total income for the period 2002-2014. This income is more easily affected by storms and floods than the income from industry because farm and forest are destroyed directly by storm and flood while factories can just close down during the time of disaster to mitigate the impacts.

On November 26, 2006, a tropical depression intensified into a storm and was named Dorian by the Japan Meteorological Agency (JMA). Strengthening of the storm took place over the following days and become a typhoon on November 29, 2006. Typhoon Dorian affected mostly Philippine and Vietnam with the maximum wind speed of 195 km/h. Dorian struck southern Vietnam on December 5, 2006 as a tropical storm and after that it diminished to a tropical depression. Dorian hit mostly southern provinces of Vietnam such as Ba Ria-Vung Tau, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, and Ca Mau. According to the Centre for Research on the Epidemiology of Disasters (CRED), typhoon Dorian killed 95 people and caused property damage of 456 million USD in Vietnam. For more details, see the map of Vietnam and track of typhoon Dorian in Figure 1.



Figure 1. Map of Vietnam and track of typhoon Durian

Source: Authors' preparation using data from Japan Meteorological Agency

In this study, typhoon Durian was selected as a typical disaster for the case study on three accounts. Firstly, typhoon Durian was one of the top five natural disasters happened in Vietnam from 2002-2014 (Desinventar, 2018). Secondly, typhoon Durian mostly affected the southern provinces of Vietnam that are notably characterized with a low frequency of natural disasters compared to the central and northern provinces of Vietnam.

This allows a good choice of Ben Tre - a southern province as the treatment group as this province was affected by Durian but not affected by any other disasters afterward. Thirdly, 2006 is an appropriate timing to analyze possible impacts of the typhoon because the required economic data are essentially available both prior and post the typhoon. Specifically, data on disaster damage and characteristics of 63 provinces of Vietnam are available from 2002-2006 for choosing the control groups and data on income per capita are available from 2007-2014 for estimating the effects of typhoon Durian.

3. Methodology

3.1. Synthetic control method

Synthetic control method (SCM) is considered a quasi-experiment in which the result is the difference between treatment group and control group. This method was first introduced by Abadie and Gardeazabal (2003) in a study of the effects of political conflicts on economic growth in the Basque Country. SCM was then applied in the study of Abadie *et al.* (2010) which evaluate the effect of the tobacco control program in California in 1988 on the consumption of tobacco. This method was also considered as a bridge between quantitative researches based on large sample and qualitative researches based on small sample (Abadie *et al.*, 2015). Applications of SCM require a number of identification assumptions that are commonly used in quasi-experimental methods including independence between causing factor and control group, no spillovers cross units, no exogenous shocks, and the common support assumption. These assumptions have been discussed in detail in previous studies (Cavallo *et al.*, 2013; Adhikari and Alm, 2016).

Independence between causing factor and control group requires that the control group be not affected by typhoon Durian. In order to satisfy this assumption, we remove all the province that were affected directly by typhoon Durian including Ba Ria-Vung Tau, Tra Vinh, Soc Trang, Bac Lieu, and Ca Mau (see the map of Vietnam in figure 1). In the aftermath of typhoon Durian, income spillover effects might occur to the provinces nearby Ben Tre because the reconstruction process places a surge in demand for labours and materials from neighbouring provinces. We can partially satisfy this assumption by excluding from the control group all provinces bordered with the provinces affected by typhoon Durian including Ba Ria-Vung Tau, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, and Ca Mau. This removes the following provinces from control group: Binh Thuan, Dong Nai, Tien Giang, Vinh Long, Hau Giang, and Kien Giang.

No exogenous shocks require that control groups be not affected by typhoon Durian and any other disasters during the time investigated. There are no such provinces because Vietnam is usually affected by floods and storms. Following Cavallo *et al.* (2013), we consider the magnitude of natural disasters based on which we select control groups as the provinces that were neither affected by typhoon Durian nor affected by “*large disasters*”. We define large disasters based on the severity of damage, measured by the number of deaths and missing and the number of houses destroyed and damaged (see table 1). We choose two control groups to include provinces that did not suffer from top 1% and 10% of total disaster damage, respectively. Top 1% are provinces that have greater than 20 deaths and missing and greater than 3297 houses destroyed and damaged per million people in one year. Top 10% are provinces that have greater than 6 deaths and missing and greater than 379 houses destroyed and damaged per million people in one year. Threshold numbers are calculated based on the percentile of provincial damage for the period 2002-2014.

We call these two control groups as Synth1% (including 19 provinces: Bac Ninh, Binh Duong, Binh Phuoc, Ca Mau, Dak Nong, Dien Bien, Gia Lai, Hai Duong, Hoa Binh, Hung Yen, Khanh Hoa, Lam Dong, Nam Dinh, Nghe An, Ninh Thuan, Tay Ninh, Thanh Hoa, HCM City, Tuyen Quang) and Synth10% (including 9 provinces: Bac Ninh, Binh Duong, Binh Phuoc, Gia Lai, Hai Duong, Hung Yen, Lam Dong, Tay Ninh, HCM City).

The common support assumption requires provinces included in the control group have similar characteristics to those of Ben Tre. Practically, this assumption is well addressed by the SCM as this method can produce counterfactual by a weighted combination of provinces in the control group. SCM uses algorithm to minimize the differences between treatment group and control group of specific of interest which are Income per capita and its predictors.

3.2. Modelling

We call J the number of observations in control groups which consists of 19 and 9 provinces in two cases of analysis. Ben Tre is one observation in treatment group. Therefore, we have a total of J+1 observations in the dataset. Following Abadie *et al.* (2010), let Y_{it}^N be the income per capita that would be observed for province i at time t that was not affected by disasters and Y_{it}^I is the income of province that was affected by disasters. For provinces, $i = \overline{1, J+1}$ and $t = \overline{1, T}$. Let T_0 is the number of period before typhoon Durian happening ($1 < T_0 < T$). So for the period before the disaster, we have $Y_{it}^N = Y_{it}^I$. For period after the disaster we use $\alpha_{it} = Y_{it}^I - Y_{it}^N$ represent for the effect of the disaster to province i at time t for $t = \overline{T_0 + 1, T}$. Our interest is to compare the income of Ben Tre province that was affected by typhoon Durian with the income of other provinces that were not affected by the disaster. As such we will compute:

$$\alpha_{it} = Y_{it}^I - Y_{it}^N \quad \text{for } t > T_0 \tag{1}$$

Of which Y_{it}^I is the per capita income of Ben Tre province and Y_{it}^N is the per capita income of the control group or per capita income of Ben Tre province if typhoon Durian did not happen. Y_{it}^I is observed, but we do not know Y_{it}^N . SCM assumes that Y_{it}^N is weighted average of Y_{jt} for $j = \overline{2, J+1}$ or it can be calculated by this equation:

$$Y_{it}^N = \sum_{j=2}^{J+1} w_j Y_{j,t} \quad \text{with the constraints: } w_j > 0 \text{ and } \sum_{j=2}^{J+1} w_j = 1 \tag{2}$$

In estimating w_j , we denote the matrices for the calculation as follows:

$$W = \begin{bmatrix} w_2 \\ w_3 \\ \cdot \\ \cdot \\ w_{J+1} \end{bmatrix} \quad X_1 = \begin{bmatrix} X_{11} \\ X_{12} \\ \cdot \\ \cdot \\ X_{1K} \end{bmatrix} \quad X_0 = \begin{bmatrix} X_{21} & X_{31} & \cdot & \cdot & X_{J+1,1} \\ X_{22} & X_{32} & \cdot & \cdot & X_{J+1,2} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ X_{2K} & X_{3K} & \cdot & \cdot & X_{J+1,K} \end{bmatrix} \quad V = \begin{bmatrix} V_1 & 0 & \cdot & \cdot & 0 \\ 0 & V_2 & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \cdot & \cdot & V_K \end{bmatrix}$$

W is the matrix (J x 1) that contains the weight of the observations in the control group. X_1 is a matrix (K x 1) that contains explanatory variables for the changing of income per capita. X_0 is the matrix (K x J) containing the explanatory variables for the per capita income of the control group, which are similar to X_1 . V is the non-negative diagonal matrix. From the notation we have $(X_1 - X_0W)$ is the difference between the treatment group and the control group. SCM estimates W_j by minimizing this difference between the treatment group and the control group or minimizing the distance:

$$\|X_1 - X_0W\|_V = \sqrt{(X_1 - X_0W)'V(X_1 - X_0W)} \tag{3}$$

According to Abadie and Gardeazabal (2003), the matrix V represents the importance of the explanatory variables and can be defined by researchers. In this study, we assume that every explaining variable is equally important and accordingly set V matrix to unity.

3.3. Statistical significance

From equation (1), we denote the estimated impact as $\hat{\alpha}_{it} = Y_{it}^I - \hat{Y}_{it}^N$ where \hat{Y}_{it}^N is the estimated value of control group. But we are not sure about the significance of the estimated value because of possible errors in data

collection and estimation. So, we have to test the significance of the value $\hat{\alpha}_{1,t}$. Following Abadie *et al.* (2010), the estimated value will be tested by permutation test which is also called Placebo test.

In the permutation test, we assume that every province in the control group was also hit by typhoon Durian while they were actually not hit and we apply SCM accordingly to estimate these counterfactual impacts. This yields a distribution of the estimated values of all provinces in the control group. We then compare the estimated value of the treatment group and the distribution of estimated values of control group. Statistical significance is measured by P_value, calculated as follows:

$$P_value_t = \Pr(\hat{\alpha}_{j,t}^{PL(j)} \leq \hat{\alpha}_{1,t}) \quad \text{where } j = \overline{2, J+1} \quad (4)$$

P_value_t is the probability that estimated value of the treatment group is greater than estimated values of the control group in the year t. This value will be calculated and presented details in table 3.

4. Data

Data for this study includes natural disasters and economic data. Natural disasters data of 63 provinces in Vietnam from 2002 to 2014 were retrieved and compiled from Desinventar (2018) which was supported by United Nations Office for disaster risk reduction. Total number of observations at provincial level is 819. The Desinventar data show the post-natural disaster damages represented by number of deaths, missing and number of houses destroyed and damaged for 63 provinces of Vietnam, as described in detail in table 1.

Table 1. Total natural disaster damages in Vietnam during 2002-2014

No.	Provinces	Deaths and missing/ mill.person	Houses destroyed and damaged/ thous.person	No.	Provinces	Deaths and missing/ mill.person	Houses destroyed and damaged/ thous.person
1	An Giang	37.7	103	33	Kien Giang	0.9	0.2
2	B.Ria-V.Tau	65.2	8.5	34	Kon Tum	45.4	2.4
3	Bac Giang	9.6	2.7	35	Lai Chau	4.4	0.0
4	Bac Kan	84.3	29.3	36	Lam Dong	80.7	1.0
5	Bac Lieu	10.4	1.8	37	Lang Son	32.9	7.4
6	Bac Ninh	1.9	0.0	38	Lao Cai	144.8	2.8
7	Ben Tre	13.5	103.2	39	Long An	176.1	5.5
8	Binh Dinh	144.1	24.8	40	Nam Dinh	19.9	9.0
9	Binh Duong	2.5	0.3	41	Nghe An	74.7	22.9
10	Binh Phuoc	0.0	0.1	42	Ninh Binh	390.9	14.6
11	Binh Thuan	17	4.8	43	Ninh Thuan	45.1	14.1
12	Ca Mau	4.1	1.9	44	Phu Tho	3.3	0.6
13	Can Tho	19.2	80.0	45	Phu Yen	67.6	2.3
14	Cao Bang	54.6	6.0	46	Quang Binh	12.2	9.3
15	Da Nang	143.5	16.0	47	Quang Nam	31.7	2.8
16	Dak Lak	44.5	2.1	48	Quang Ngai	29.5	9.9
17	Dak Nong	11.9	2.6	49	Quang Ninh	194.9	2.4
18	Dien Bien	29.9	2.9	50	Quang Tri	252.2	650.4
19	Dong Nai	1.9	1.9	51	Soc Trang	301.3	75.9
20	Dong Thap	72.5	39.9	52	Son La	426.7	20.6
21	Gia Lai	11.5	0.3	53	Tay Ninh	66.7	11.5

22	Ha Giang	174.5	8.1	54	Thai Binh	118	182.5
23	Ha Nam	2.5	0.0	55	Thai Nguyen	1.5	0.9
24	Ha Noi	3.5	0.0	56	Thanh Hoa	74.6	11
25	Ha Tinh	115.6	95.4	57	T.T Hue	1.9	0.1
26	Hai Duong	0.6	0.1	58	Tien Giang	5.6	23.2
27	Hai Phong	8.1	7.6	59	Tra Vinh	28.3	2.2
28	Hau Giang	0.0	7.1	60	Tuyen Quang	12.9	1.7
29	HCM City	0.9	0.2	61	Vinh Long	90.8	18.1
30	Hoa Binh	45.4	2.4	62	Vinh Phuc	13.1	18.2
31	Hung Yen	4.4	0.0	63	Yen Bai	2.0	3.3
32	Khanh Hoa	80.7	1.0	Average		67.0	28.0

Source: compiled by authors from Desinventar.net

Economic data was collected from General Statistics Office of Vietnam (GSO, 2018) from 2002-2014. Data includes aggregate income per capita (A_Income) which represents our key dependent variable, and income disaggregated by sources such as income from salary (S_Income), income from agriculture, fishery and forestry (AFF_Income) and income from industry, construction, trade, and services (NAFF_Income).

Following Noy and Vu (2010) who studied the impact of natural disasters on economic growth in Vietnam, we used Infrastructure, Trade, Education, Healthcare, all measured at the provincial level, as control variables in the present study. Infrastructure, measured by the amount of goods transported, is a main factor explaining economic growth as suggested by Sahoo and Dash (2009); Chakamera and Alagidede (2018) in their studies on the role of infrastructure on economic growth in South Asian and Sub Saharan Africa countries.

Domestic Trade, measured by retail sales per capita as proxy for Trade, is considered an important indicator underlying commercial activities and hence economic output and income (Noy and Vu, 2010).

Healthcare measured by the number of doctors per capita represents the intensity of healthcare whereas Education measured by the number of students per capita represents the level of education, as commonly done in previous studies (Ramirez and Nazmi, 2003; Noy and Vu, 2010; Kuo and Shiu, 2016).

In line with a cross-country study by Cavallo *et al.* (2013) estimating the impact of natural disaster on economic growth during 1970-2008, we also use Land, measured as land area per capita as a control variable. Income from agriculture, fishery and forestry is affected by production from agriculture, fishery, and forestry. According to Tran (2014), paddy is a common agricultural crop, wood and fish are the common output for forestry and fishery, respectively.

Hence, when estimating income from agriculture, fishery, and forestry we include annual yield of paddy (Paddy), annual production of wood (Wood), and annual production of fish (Fish) as control variables.

Data for all control variables is collected from GSO (2018). All economic variables were converted to fixed price in 2010 using respective consumer price indices. Table 2 presents the average value of economic data of the case study.

Table 2. Average value of all variables

Variables	Unit	Before typhoon Durian from 2002-2006			After typhoon Durian from 2007-2014		
		Ben Tre	Synth1%	Synth10%	Ben Tre	Synth1%	Synth10%
A_Income	Thous.VND/month	465.25	504.65	589.7	723.72	815.2	974.78
S_Income	Thous.VND/month	132.71	147.67	195.6	216.95	320.48	387.7
AFF_Income	Thous.VND/month	167.4	171.51	157.28	229.99	216.63	233.43
NAFF_Income	Thous.VND/month	89.78	109.35	143.34	159.44	185.08	245.48
Trade	Mill.VND/person/year	3.58	4.86	5.93	11.39	14.58	7.94
Infrastructure	Ton*km/person/year	0.18	0.31	0.32	0.27	0.54	0.54
Healthcare	Doctors/thous.person	1.71	1.76	1.63	2.31	2.13	1.99
Education	Students/thous.person	192.51	228.31	229.38	165.17	174.92	194.38
Land	Km ² /thous.person	1.84	4.65	4.58	1.87	5.18	4.12
Paddy	Ton/person/year	0.28	0.67	0.46	0.28	0.48	0.5
Wood	M ³ / person/year	0.01	0.05	0.03	0.00	0.06	0.05
Fish	Ton/thous.person/year	105.77	59.59	20.7	217.94	56.54	34.94

Source: calculated by Authors from GSO.

5. Results and discussions

We estimated the impacts of typhoon Durian on aggregate income per capita (A_Income) and three disaggregated sources of income including income from salary (S_Income), income from agriculture, fishery and forest (AFF-Income) and income from industry, construction, trade and services (NAFF_Income), respectively. To estimate the impact of typhoon Durian, SCM was used to compute a counterfactual. This means that control groups should have the same characteristics as treatment group. In this study, control groups were provinces that have the same income, land area, infrastructure, trade, healthcare, and education as Ben Tre province. For a robust result, we analyze two control groups including provinces that did not suffer from top 1% and 10% of total disaster damage. We call these two cases as Synth1% and Synth10%. Figure 2 shows the trend income of Ben Tre and income of control groups and table 3 shows placebo test for the estimated results.

The results show that typhoon Durian has negative impact on aggregate income per capita both in the short-term and long-term. The monthly average reduction is 56,925 VND for the period 2007-2014. The reduction of income accounts for 7.9% of total household income. This finding supports the hypothesis “no recovery” as also confirmed by Hsiang and Jina (2014). This hypothesis argues that disasters destroy productive capital or durable consumption goods and households do not have enough resources to recover from this negative impact. The recovery is even harder for poor/developing countries that are endowed with limited resources and underdeveloped infrastructure systems (Noy & DuPont, 2018). Vietnam is not an exception with income per capita of 2006 at current prices is 636,000 VND/month, equivalent to 477 US dollars/year (GSO, 2018). In addition, Ben Tre is situated in middle of the Mekong river delta where there are nine rivers passing through the region. The use of ferries, rather than bridges, for crossing the river is still common, making it harder for households in Ben Tre to access resources in other provinces.

With respect to disaggregated sources of income, the estimated impact of the typhoon differs as per income source. Income from salary and income from agriculture, fishery and forest are found negatively affected by typhoon Durian from 2007-2014 while there is a positive impact of the typhoon on income from industry, construction, trade, and services from 2009-2012. Durian reduced income from salary by 55,395 VND and reduced income from agriculture, fishery, and forestry by 106,047 VND monthly for the period 2007-2014

compared with the two control groups. This occurred because many factories could not operate in the aftermath of the disaster, workers did not receive salary and farmers did not have income from farming due to the crop damage. On the contrary, income from industry, construction, trade, and services of Ben Tre province was higher than that of provinces in the control groups in the period of 3 to 5 years after the typhoon. Theory of creative destruction process offers a possible explanation whereby the reconstruction activities that take place in the aftermath of natural disasters can raise the demand for construction and related services. The impact could be attributed to an increased demand for post-disaster reconstruction as proposed by Cavallo *et al.* (2013); Caballero and Hammour (1994). Since 2012, the results show a negative impact again, probably because the demand of reconstruction disappeared.

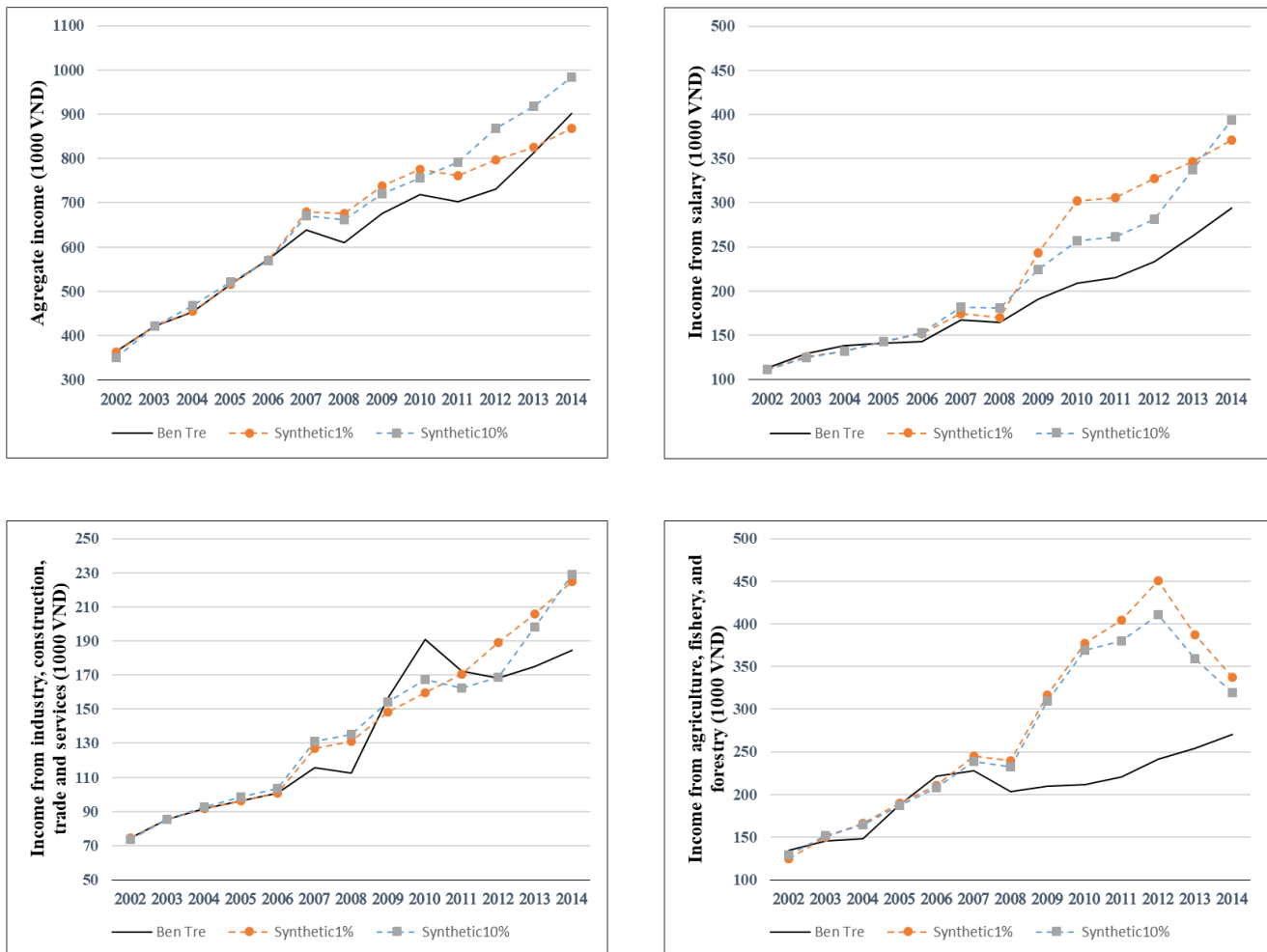


Figure 2. Income per capita, aggregated and disaggregated: Ben Tre vs. control provinces

The significance of the results is especially important. In this case, one could question whether income of Ben Tre province was indeed reduced by typhoon Durian or that was only random results. Following Abadie *et al.* (2010), we use the permutation test to check the results. SCM is applied for the provinces included in the control groups as if they were affected by typhoon Durian. This so-called Placebo test provides a distribution of the estimated results, based on which we compare the results between the aggregate income of Ben Tre and

provinces in the control groups. The test results as presented in table 3 indicate that typhoon Durian caused a statistically significant negative impact on all the sources of income after typhoon Durian except income from industry, construction, trade, and services for the period 3-5 years after the event.

Table 3. Statistical significance of estimated results by Placebo test

Year	Aggregate income		Income from salary		Income from industry, construction, trade, and services		Income from agriculture, forestry, and fishery	
	Synth1%	Synth10%	Synth1%	Synth10%	Synth1%	Synth10%	Synth1%	Synth10%
2007	-3.52***	-2.46**	-2.23**	-2.00**	-3.17***	-3.20****	-2.71***	-0.47
2008	-5.27***	-3.41***	-2.28**	-2.27**	-3.10**	-2.83**	-5.45***	-1.98**
2009	-4.48***	-2.64**	-5.54***	-2.31**	0.16	-0.99	-11.84***	-3.02***
2010	-3.63***	-1.96**	-6.52***	-2.19**	2.43	0.95	-12.87***	-3.00***
2011	-4.18***	-3.55***	-6.58***	-2.69**	-0.4	-0.21	-10.56***	-3.50***
2012	-4.35***	-4.72***	-6.45***	-2.29**	-2.04**	-0.66	-9.28***	-3.86***
2013	-2.39**	-4.48***	-4.96***	-2.48**	-1.94**	-1.23	-7.59***	-3.37***
2014	-0.81	-3.14***	-3.92***	-2.54**	-1.81**	-1.48*	-4.65***	-3.04*

Note: Table 3 presents t-statistics of the difference in aggregate income per capita between the treatment group and control group. *, **, *** represent the significance at 10%, 5%, and 1% respectively. *Source:* estimated by authors.

Conclusions

We applied SCM to investigate the effect of typhoon Durian that occurred in Ben Tre province (Vietnam) in 2006 on aggregate income per capita and income disaggregated by sources. The analysis uses data on natural disasters and economic data at the provincial level during the period 2002-2014. Our results document an income reducing effect of the typhoon Durian on aggregate income per capita of Ben Tre and confirm that the effect lasted eight years after the event. This finding provides support of the hypothesis of no recovering after natural disasters, as also confirmed by previous studies for other countries (Coffman and Noy, 2012; Barone and Mocetti, 2014; Hsiang and Jina, 2014).

By source of income, our results also reveal a negative and long-lasting impact of typhoon Durian on income from salary and income from agriculture, fishery, and forest. The most affected income sources include income from agriculture, fishery, and forestry. A possible policy implication drawn on this finding is that policymakers should prioritize post-disaster relief programs to households that primarily receive income from agriculture, fishery, and forestry. Better targeted post-disaster relief program will help speed up the recovery process, especially for disasters similar to Durian.

The study merits some attentions for future research. One of SCM assumptions requires no spillover effect from the affected area to the control group. We partially controlled for this by technically removing from the control group provinces that are bordered with Ben Tre. In order to fully satisfy this assumption, more empirical studies are needed to estimate the spillover effects of natural disasters. In addition, income from agriculture, fishery, and forest collected from the General Statistics Office of Vietnam are aggregate data for the entire sector. Therefore, the present analysis could not estimate the impact of natural disasters on income of each sub-sector of agriculture, forestry or fishery. If one could separate income from agriculture, forestry, and fishery, the results would be more policy relevant.

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