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THE SYNTHETIC REGRESSION METHOD: HOW THE INDIAN OCEAN TSUNAMI AFFECTS GROWTH TRAJECTORIES 12

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ac.id, shanti@petra.ac.id Abstract In recent works, scholars have widely used the synthetic control method (SCM) for analyzing the effect of a catastrophic disaster on economic growth. Unlike the traditional SCM, we propose the so-called synthetic regression method to choose a suitable synthetic control group by employing a comparing series procedure. We then use the selected group to estimate our outcomes of interest.

We apply the synthetic regression **method to** examine **the** causal **effects of** 1

the 2004 Asian tsunami on economic growth in Aceh, the Indonesian province severely hit by the tsunami. Our results show that the tsunami has an unintended effect on Aceh's economic growth performance. The findings of the paper lead us to a better method for analyzing the growth trajectories, particularly for Aceh

after the 2004 tsunami Keywords: Natural disasters, Economic growth, Synthetic control method, Comparing series, Synthetic regression method. 1. INTRODUCTION An influential stand of literature on the economics of natural disasters has been devoted to assess the economic effects of such events. The standard taxonomy classifies damages caused by disasters into three classes: direct damages that entail the loss of productive investments (e.g. destruction of fixed assets and inventories), indirect damages that encompass the decline in the production of goods and services, and secondary effects that involve the evolution of macroeconomic variables (Peeling et al., 2002; ECLAC, 2003). This paper assesses the change in the growth trajectories of Aceh, the Indonesian province exposed to the 2004 tsunami. In practice, we adopt an experimental design in which the catastrophic natural disaster or the treatment is supposed to generate a jump or an interrupted in the time series data. Previous research studied the conditions before and after that interruption in different methods. Halim and Jiang (2013) used the

interrupted time series analysis **with** a **segmented regression** method **for**	7

analyzing

the effect of operation 24 hours on reducing collision in the City of Edmonton.	11

Hamed et al. (1999) employed **a diffusion model with jumps to investigate the** impact **of** the **Gulf crisis** on **traffic collisions in Jordan.**	7

The interrupted time series and diffusion models will produce satisfactory results if we are able to compare the before and after conditions for a single time series. On the contrary, the synthetic control method (SCM) offers us the opportunity to select an appropriate control group based on multiple time series, and it allows us to construct the synthetic control unit from a group of untreated units. However, the SCM has several drawbacks. For instance, in

some cases, it may not even be possible to obtain a weighted combination of untreated units such that	1

some restrictions for constructing the SCM are satisfied. This condition will lead to a poor fit.

Even if there is a synthetic control unit **that provides a good fit for the treated** unit, **interpolation biases may be large if the simple linear model**	1

does not hold over the entire set of regions in any particular sample	1

(Abadie et al., 2010). Therefore, in this paper, we propose the so-called synthetic regression method. Basically, it is carried out in two steps. First, we use the comparing series method as Franke and Halim (2007) to select a suitable control group. In our case, we need to choose a proper synthetic control group for the Aceh Province. In the second stage, we use the selected group to estimate economic growth that would have been observed for Aceh in the absence of the disaster. The economic growth is estimated using linear regression. 2. METHODOLOGY In this section, we give an overview of the two methods for studying the evolution of Aceh's economic growth after the tsunami. They are the synthetic control method and the synthetic regression method. 2.1. Synthetic Control Method We assume that the Indian Ocean tsunami in 2004 is an exogenous event, and it produces a sizeable effect on the exposed province. The SCM constructs a counterfactual group whose outcomes are compared to the Aceh Province. The synthetic group is a weighted combination of the unexposed provinces that resemble Aceh in economic characteristics before the disaster took place. After the occurrence of the disaster, we

estimate the counterfactual situation of Aceh **in the absence of the** **15**

tsunami through the outcomes of the synthetic group. We formalize this concept as follows. We observe 26 provinces in Indonesia for the period . Let be the Aceh Province, and be the other provinces. Here, we let be the year when tsunami struck Aceh and be the outcome variable which evaluates the impact of the tsunami on province at the time . Additionally, is the outcome variable that refers to the tsunami and is the outcome variable when the tsunami did not occur.

Our goal is to estimate the effect of the tsunami **on the** economics of **the** **4**

Aceh Province during 2005-2011.

This effect is defined as the difference between the **4**

outcome variable that refers to the tsunami and when it did not occur, or: , (1) However, the in those periods is unobserved. Therefore, this outcome will be estimated synthetically using the SCM. Following Abadie et al. (2010),

to construct the **synthetic control, we define a** (25x1) **vector of weights** **4**

such that for and .

Abadie and Gardeazabal (2003) and Abadie et al. (2010) choose **16**

such that (2) For calculating the synthetic control methods, we use R.3.0 with Synth-R. packages (Abadie et al., 2011). 2.2. Synthetic Regression The synthetic regression method is a simple linear

regression model: , where Y is **the dependent variable,** 14

in this case is Aceh's economic growth,

g(.) is a linear function and **X** 14

is the independent variables. Those independent variables are the synthetic regions whose GRDP/Capital is similar to the growth rate of Aceh. The synthetic regions are chosen by using a comparing series procedure, as explained in the following section. Comparing Series We consider two series of the form (Franke and Halim, 2007) ; ; (3) where are independent with zero mean and finite variance, = . are the general functions in which represent the series for Aceh and represent the series other than Aceh. We want to find a synthetic region which has similar economic characteristics as Aceh,

i.e., we want to test the hypothesis . **are** 8

arbitrary functions. Because is equidistant, we can estimate by using the Priestley-Chao (1972) kernel estimator as: ; (4) where

denotes a rescaled kernel function. is a probability density symmetric around zero, 6

is the bandwidth to control the smoothness of the estimated functions.

To perform the test, we measure the **distance between the** 6

estimated functions and .

We reject the null hypothesis if that distance **is** 8

too large. The distance itself is defined as: (5) In the same vein, we

reject the null hypothesis at a level of 8

if , where is approximated by using a bootstrap procedure. The bootstrap procedure is started by estimating the residuals: ; (6) We then generate the bootstrap residuals and consider two bootstrap series which are constructed as: (7) The bootstrap for the kernel estimators is then calculated by using: (8) The

bootstrap test statistic can be constructed as: (9) **To** 6

get a Monte Carlo approximation of quantile , we generate the realization of repeatedly as many as B (e.g. B = 10,000). 3. RESULTS AND DISCUSSION We study the causal effect of catastrophic

natural disasters on **the short- and medium-** 28

term economic growth. We take a direct case of the 2004 Asian tsunami in Indonesia. One day after Christmas in 2004 at 00.59 GMT,

a 9.0 Richter **-magnitude** earthquake **struck the west coast of Sumatra,** 17

a major island in the western part of Indonesia. It subsequently generated ferocious tsunami waves in the Aceh Province of Sumatra. This catastrophic disaster is considered as

one of the worst tsunamis **in human history.** According to **the** official statistics, **the** 18

death toll of the Aceh tsunami was more than 165,000 people

and over a half **million people** were **displaced. The** total estimate **of** 24

economic damages and losses was approximately US$ 4.5 billion corresponding to 97.4% of Aceh's gross regional domestic product (GRDP) in 2003 (Athukorala and Resosudarmo, 2005; Athukorala, 2012). 3.1. Data The data set was taken from the Indonesian Central Bureau of Statistics (BPS) and includes 26 Indonesian provinces1. The data set is annual and covers the period 1994-2011. All nominal variables are converted in 2000 prices. The description of the variables is given below. The outcome variable is economic growth. It is measured by the change in

gross regional domestic product (GRDP) per capita. The 25

predictors of economic growth are: - The sectoral value added consists of nine major sectors in the economy, that is, agriculture, mining and quarrying, manufacturing, construction, utilities, trade, hotel, and restaurant, transportation and communication, finance, and services. They are also in growth rate. - The variable of investment is defined as the

growth rate of gross fixed capital formation. - The growth rate of 13

government consumption. - **The**

proxies for human capital are of the enrollment numbers of

primary school, junior high, senior high school, and university. **19**

They are expressed in logarithms. The other variables are adult literacy rate and years of schooling. - Population density is measured as total population divided by land area in kilometer square. 1 Prior to the fall of the New Order Regime in 1998, Indonesia had 27 provinces. It turned to be 26 provinces after East Timor gained its independence in 1999. The remaining provinces have proliferated today, becoming 34 provinces. However, to maintain consistency, our analysis still uses 26 provinces. 3.2. Results 3.2.1 Using Synthetic Regression Method We first compare the growth rate of the gross regional domestic product per capita (or GRDP/Cap) of each of the 25 provinces to the Aceh Province by using the comparing series method. We find that Riau, South Sumatra, Jogjakarta, East Nusa Tenggara, Central Kalimantan, and East Kalimantan have similar GRDP/Cap characteristics as Aceh. We then formulate a linear regression model with the GRDP/Cap of Aceh as the dependent variable and the GRDP/Cap of the selected regions as the independent variables. The estimated coefficients show that the GRDP/Cap of Aceh closely resembles Riau, East Nusa Tenggara, and East Kalimantan. Table 1.The estimated

regression coefficients Estimate **Std. Error t value Pr(>|t|) Intercept -0.** **5**
1134 **0.** 02266 -5.007 **0.** 000398 *** Riau **-1.** 3287 **0.** 64393 -2.063 **0.**

063496 South Sumatra -0.3029 0.29518 -1.026 0.326845 Jogjakarta -0.8098 0.50934 -1.59 0.140176 East Nusa Tenggara 3.6155 0.90144 4.011 0.002048 ** Central Kalimantan 0.53476 0.54444 0.982 0.347097 East Kalimantan -0.9485 0.44009 -2.155 0.054147 Using those three regions, we formulate the second linear model and plot the prediction of that model as the GRDP/Cap of the synthetic region against the GRDP/Cap of Aceh (Fig. 1). From that figure, we can see that the GRDP/Cap of Aceh and the synthetic group is very similar. The figure also confirms that after 2004 (the year of the Asian tsunami), the GRDP/Cap of the synthetic regions is higher than the Aceh Province.

This finding lends support to the hypothesis **that the** **10**

catastrophic tsunami negatively affects the GRDP/Cap growth. Table 2.The estimated

regression coefficients Estimate **Std. Error t value Pr(>|t|) Intercept -0.** **5**
09590 **0.** 02054 -4.668 **0.** 000362 *** Riau **-1.** 15996 **0.** 48452 -2.394 **0.**

031223* East Nusa Tenggara 2.42959 0.54078 4.493 0.000506 *** East Kalimantan -0.91195 0.40563 -2.248 0.041192 * 25 20 15 10 5 0 -5 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 -10 -15 GRDP/Cap_Aceh GRDP/Cap_Synth Fig. 1 GRDP/Cap: Aceh vs Synthetic Regions 3.2.2 Using

Synthetic Control Method According to **the synthetic control method** (SCM), **the** 26

Aceh's growth trajectory prior to the tsunami is best represented by a combination of DKI Jakarta, Riau, East Nusa Tenggara, Central Kalimantan, and East Kalimantan, the provinces with positive weights (Table 3).

It is important to note that these **synthetic control** 10

provinces are also captured in our proposed method, with the exception of DKI Jakarta. However, we cast some doubts on the SCM results since the GRDP/Cap for the synthetic regions is above the GDP/Cap for Aceh in most of the years, except in the year 2002 (Fig. 2, left). In addition, the GRDP/Cap gap of Aceh and the synthetic provinces is also negative, apart from the year 2002 (Fig. 2, right). Table 3.Synthetic Weight for Aceh Province

North Sumatra West Sumatra Riau Jambi South Sumatra Bengkulu Lampung DKI Jakarta West Java Central Java Jogjakarta **East Java Bali** Weight Province 0 **West Nusa Tenggara** 0 **East Nusa Tenggara** 0.276 **West Kalimantan** 0 **Central Kalimantan** 0 **South Kalimantan** 0 **East Kalimantan** 0 **North Sulawesi** 0.106 **Central Sulawesi** 0 **South Sulawesi** 0 **Maluku** 0 **Papua** 3

0 0 Weight 0 0.239 0 0.142 0 0.235 0.001 0 0 0 0 20 10 GRDP_Cap 0 -10 Aceh SyntheticAceh 1995 2000 2005 2010 year 30 20 Gap in GRDP_Cap Growth 10 0 -10 -20 -30 1995 2000 2005 2010 Year Fig. 2 GRDP/Cap: Aceh vs Synthetic Regions (left), GRDP/Cap Gap: Aceh vs Synthetic Regions (right) 3.3 Discussion It is well known that, in some instances, the

synthetic control method (SCM) **may result in poor** model **fit.** 23

Under this condition, it is recommended for not using the SCM (Abadie et al., 2010). In our case, the SCM does not give a reasonable choice of the synthetic regions, particularly for choosing DKI Jakarta (the capital of Indonesia) as one of the synthetic regions for Aceh in terms of the GRDP/Cap growth. The graphical plot of the GRDP/Cap yearly basis between Aceh vis-à-vis DKI Jakarta shows that most of the time, the GRDP/Cap of DKI Jakarta is above Aceh, except in the year 1998 and 2002 (Fig. 3). With respect to the unusual trend in 1998, we argue that Aceh's economy grew stronger than the economy of DKI Jakarta even though the two provinces experienced worse economic downturns

as a result of the Asian financial crisis. 21

2 This argument is fairly acceptable since the crisis led to the deepest contractions in the industrial and

service sectors, the two sectors that dominated DKI Jakarta's economy, whereas the main pillars of Aceh's economy (i.e. the agricultural and oil and gas sectors) were less affected. As for the year 2002, high price levels for oil and gas and a substantial amount of Special Autonomy Fund (Dana Otsus) from the central government partly contributed to Aceh's remarkable economic growth. On the other side, both Aceh and the three synthetic regions that are chosen by our proposed method seem to follow a similar economic growth path from year to year, except for the year of 2002 (Fig. 3).3 Therefore, we highlight that our chosen method gives more reasonable results as compared to the SCM. From the theoretical part, our findings suggest that the tsunami disaster

has a negative **impact on** regional economic **growth. This** evidence **is consistent with** 3

previous studies that employ the standard SCM, such as Noy (2009),

Coffman and Noy (2012), and **Cavallo et al. (forthcoming).** 22

30 30 20 20 10 0 -10 -20 "94 "96 "98 "00 "02 "04 "06 "08 "10 Aceh DKI Jakarta 10 0 -10 -20 "94 "95 "96 "97 "98 "99 "00 "01 "02 "03 "04 "05 "06 "07 "08 "09 "10 "11 Aceh Riau 2 In 1998, the Asian financial crisis severely hit Indonesia. It triggered a big riot in Jakarta and forced the Indonesian President at that time (the late President Soeharto) to end his 32 years presidency in Indonesia. 3 With regard to the rapid growth of Aceh in 2002, we just provide two plausible explanations in the previous paragraph. 30 30 20 10 0 -10 -20 "94 "96 "98 "00 "02 "04 "06 "08 "10 Aceh East Nusa Tenggara 20 10 0 -10 -20 "94 "96 "98 "00 "02 "04 "06 "08 "10 Aceh East Kalimantan Fig 3.GRDP/Cap: Aceh vs Synthetic Regions 4. CONCLUSION We show that the synthetic regression method provides more convincing results as compared to the traditional

synthetic control method. As **the** heart **of the synthetic** regression **method, the** 20

comparing series procedures are able to choose the synthetic control provinces that best resemble Aceh's economic growth trajectory. Our results are in the right direction, but we have not finished yet. Finding a well-defined approach to determine the weight of the synthetic regions instead of using simple linear regression models opens up new avenues for our future work. ACKNOWLEDGMENT The authors gratefully acknowledge financial support for this research

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