Article

Natural Disasters, Climate Change and Their Impact on Inclusive Wealth in G20 Countries

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Abstract: This paper uses the 1990-2010 natural disaster and carbon emissions data of G20 countries to examine the impact of natural disasters and climate change on the natural capital component of inclusive wealth. Our study shows that climate change and GDP have no positive impacts on the growth of natural capital. By contrast, trade openness and natural disaster frequency contribute to the accumulation of natural capital in G20 countries. There is an inverted U-shaped relationship between the growth of natural capital and the magnitude of natural disaster. Natural capital growth is not affected very much by small disasters. By contrast, large disasters tend to make the growth of natural capital fall sharply.

Keywords: natural disasters; climate change; natural capital; sustainable development

1. Introduction

Traditional development indices share a common problem of neglecting the effects of economic activities on natural environment. However, growing evidence shows that economic growth in the sacrifice of natural environment is unlikely to be sustainable. In order to examine the sustainability of economic growth, the United Nations has developed a new sustainability index, Inclusive Wealth Index, that provides a comprehensive examination of the capital asset foundation of a country’s economic activities. The capital assets that Inclusive Wealth Index examines include produced capital, human capital, and natural capital. Natural capital is the one that is most vulnerable to natural disasters and climate change. Countries that rely too much on natural capital for economic growth may even fall into the “natural resource curse”. Of the 140 sample countries surveyed in the 2014 Inclusive Wealth Report, 127 countries experienced a decline in natural capital.

Natural disasters and climate change impose a serious threat to sustainable development and the stock of natural capital. Since 1960, there have been 13,740 natural disasters worldwide, which caused 5.4 million deaths, 7.9 billion people involved, and economic losses of up to $3.3 trillion (see Figure 1). These natural disasters include: drought, earthquake, epidemic, extreme temperature, flood, insect infestation, landslide, mass movement (dry), storm, volcanic activity, wildfire, etc. Natural disasters directly affect the stock of natural capital and are shown to have a greater impact on developed countries than on developing countries (see Figure 2). Climate change also directly affects the economic growth and sustainability of countries. According to [1], due to carbon emissions from global deforestation, the average carbon emissions per hectare is about 100 tons of carbon and the economic loss per ton of carbon emissions to the atmosphere is about $50 [2]. This is a serious threat to human health, food security, terrestrial and marine ecosystems. This paper focuses on the changes in natural capital caused by natural disasters and climate changes across the G20 countries.

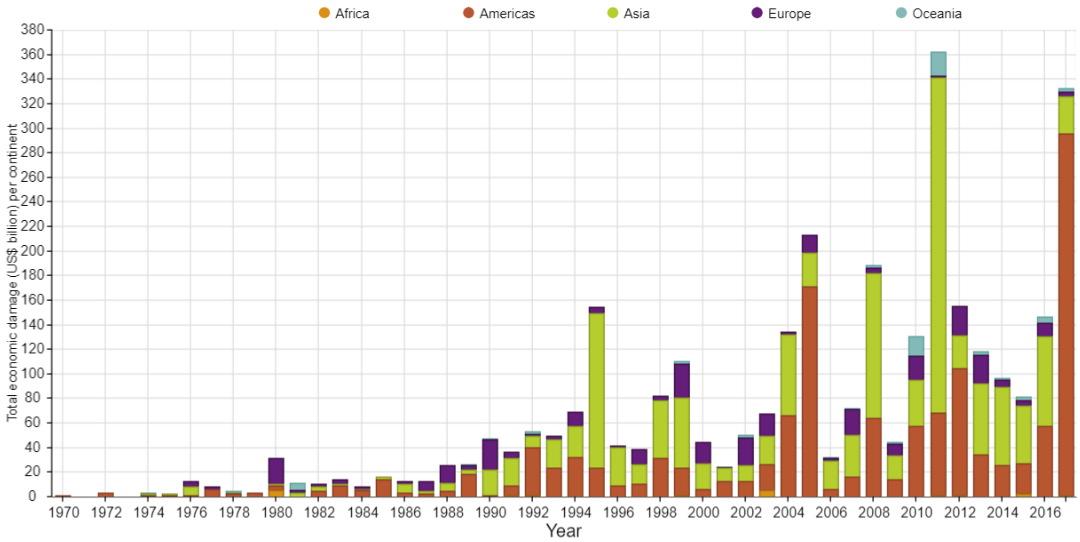

Figure 1. Economic Losses from Global Natural Disasters: 1970-2017 (Billion USD)

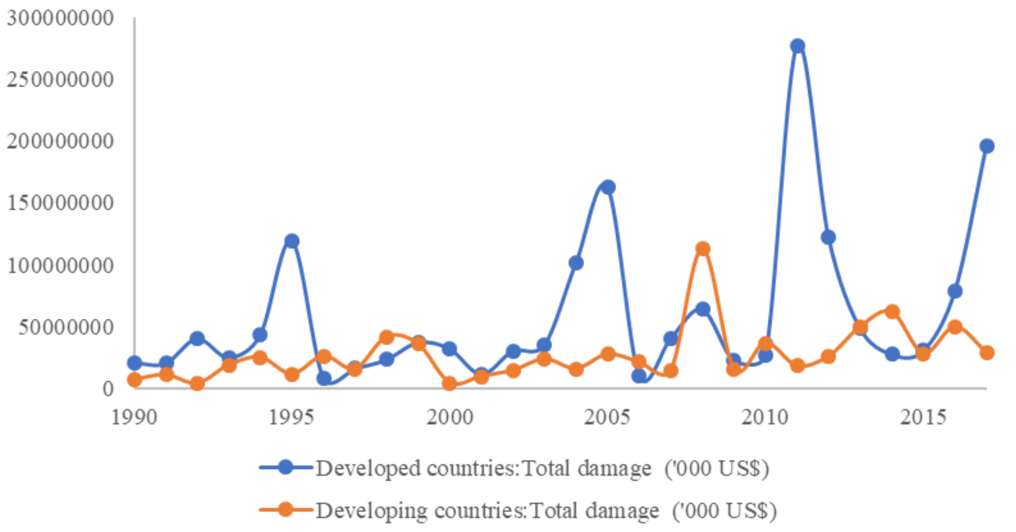

Figure 2. Comparison of Disaster Losses between Developed and Developing Countries in G20

2. Literature Review

Most of the existing studies believe that natural disasters and climate change have negative effects on economy. [3-7] quantitatively examine the impact of natural disasters on economic growth in Ethiopia, Malawi, Central America and Caribbean countries respectively. Their results show that droughts and floods can cause 1% GDP decline in these countries or regions. [8] points out that climate change is estimated to cause an overall loss of up to 5% of global GDP if no further action is taken.

The negative impact of natural disasters on countries at different income levels have been examined by the existing literature. [9] argues that in low-income countries where the level of food security is low, extreme weather conditions such as droughts and floods can lead to disruptions in the production chain, depreciation in assets, decline in demand, and slower rate in economic growth and poverty reduction. [10] points out that the negative effects of natural disasters on economic growth exist only in developing countries. [11] shows that a 1 °C temperature increase in a given year results in a 1.4% decline in per capita income, but this effect is limited to poor countries. [12] believes that natural disasters only have a minor impact on economic growth and developing countries are subject to the impact more than developed countries. [13] argues that, contrary to common sense, some relatively developed countries, rather than underdeveloped sub-Saharan African economies like Burkina Faso, are more susceptible to drought shocks. [14] distinguishes between absolute and relative losses of natural disasters. According to this study, natural disasters cause greater economic losses to high-income countries in terms of the amount of wealth but cause greater economic losses to low-income countries relative to their GDP. From 2006 to 2010, economic losses caused by natural disasters exceed 1% of GDP in the low-income countries of the Asia-Pacific region, while only 0.1% in developed countries.

The negative impacts of natural disasters on different regions within the same country have been investigated as well. [15] uses Ethiopian household panel data to explore the impact of rainfall shocks on household consumption in rural areas of the country. Studies show that rainfall shocks affect food consumption for not only current year but also subsequent years. [16] finds a significant negative impact of natural disasters on the human development index and poverty at the municipal level. [17] explores the impact of climate change on different parts of Brazil. The results show that the impact of seasonal precipitation change is different across regions of Brazil. Spring drought and summer floods have the most significant impact on Brazil's poorest regions in northeast. In addition, precipitation change tends to increase internal inequality in Brazil. [18] build National Interstate Economic Model to analyze the economic losses of the hurricane Sandy. The simulation results of the model show that within the 4 days of hurricane Sandy caused an economic loss of 2.8 billion US dollars to New York and Long Island and 10 billion US dollars to the whole country.

Some studies have examined the effects of extreme climate on productivity, imports and exports and non-economic losses. [19] use Australia's millennium drought as an extreme weather event to examine its impact on total factor productivity. The study finds that the severe drought that occurred between 2002 and 2010 caused the total factor productivity of Australian agricultural sector to fall by about 18%. [20] examine the impact of major disasters on imports and exports in 170 countries from 1962 to 2004. The study finds that extreme disasters reduce imports by an average of 0.2% and exports by 0.1%. And factors that are found to determine the size of the impact of a catastrophic event include the democracy level and the geographic size of the affected country. The lower the democracy level and the smaller the geographic size, the greater the damage is. [21] argues that in addition to economic losses, climate change can also lead to non-economic losses in terms of health, culture and environmental assets at the local and community levels.

However, some researchers believe that in spite of short-term economic losses caused by natural disasters, post-disaster reconstruction may contribute to long-term economic growth as natural disasters can accelerate the replacement of existing capital stock. This effect is referred to by some scholars as the Schumpeter Hypothesis for natural disasters. [22] examine this hypothesis that natural disasters lead to creative destruction. The study finds that only countries with relatively high levels of development would benefit from post-disaster capital renewal. [23] use natural disaster data from 89 countries in 1960-1990 and find that disaster frequency is positively correlated with human capital accumulation, total factor productivity, and economic growth. They believe that disasters provide an opportunity to upgrade capital stocks, thereby encouraging the use of new technologies. [19] also believe that in some cases, drought may even have a positive impact on productivity growth. For example, drought may contribute to the redistribution of resources from inefficient farmers to efficient farmers with better risk management. As a result, this redistribution of resources may promote industrial productivity. [24] in an econometric analysis of panel data treat precipitation changes as an additional variable and find that climate change increases US agricultural annual profits by $1.3 billion or equivalently 4%. [25-27] find that by developing earthquake-mitigating technologies and promoting institutional improvements, the losses can be mitigated and economic performance can be increased.

Some scholars (such as [29]) believe that there is no definite relationship between natural disasters and economic growth. [28] find that natural disasters have no positive effect on economy in the long run, and long-term growth depends only on technological innovation. [30] point out that natural disasters do not always have a negative impact on economic growth. In developing countries, hurricanes and earthquakes can promote industrial growth and normal-scale floods may have a positive impact on agriculture and other economic sectors. [31] extends the research period of [23] to 1990-2004, and tests the hypothesis of creative destruction. Little evidence is found for the accumulation of human capital by meteorological disasters, but geological disasters are shown to have negative impact on human capital accumulation. [32] point out that although natural disasters lead to considerable welfare losses, disasters are shown to have no significant impact on per capita GDP.

The existing research on natural disasters is focused on the impact on economic activities. However, little has been on the impact on inclusive wealth, especially natural capital. Our study of the impact of natural disaster on the G20 countries contributes not only to the study of natural capital as a foundation for sustainable development but also to the study of the extents and trends of natural disasters and climate change. This study also provides useful enlightenment on how countries can effectively use natural capital to achieve long-term sustainable development.

The rest of the paper is organized as follows: Section 3 discusses the data source and research methodology. Section 4 examines the impact of the frequency of G20 natural disasters, the number of people affected, economic losses, carbon emissions and other control variables on natural capital in inclusive wealth. And robustness testing is conducted. Section 5 provides the conclusion and policy recommendations.

3. Data and Method

3.1 Data source and description

This article is focused on G20 countries, namely, Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, Turkey, United Kingdom and United States. Saudi Arabia was excluded as the country data are incomplete. Our research considers years 1990-2010 as the sample time period due to the constraint of data availability. Natural capital data comes from the UN Inclusive Wealth Database. The natural capital assets examined in this paper include (1) forests, represented by timber and non-timber forests; (2) fisheries; (3) fossil fuels (oil, natural gas and coal); (4) mineral products (Bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin and zinc); (5) agricultural land. The total value of a certain type of natural assets is derived by multiplying the actual available quantity of the asset by the corresponding shadow price. Natural disaster data comes from the EM-DAT database. The disasters in the database meet one of the following: (1) more than 10 deaths; (2) more than 100 people affected, injured or homeless; (3) announcement of State of emergency; (4) call for international assistance. Although EM-DAT includes both natural disasters and technical and complex disasters, this article only examines the economic impact of natural disasters, which include drought, earthquake, epidemic, extreme temperature, flood, insect infestation, landslide, mass movement (dry), storm, volcanic activity, wildfire, and the like. They caused not only death, injury and homelessness but also direct or indirect economic losses that undermine the natural capital stock that a country depends on for its sustainable development. The number of natural disasters, the number of people affected, and the total loss in this paper are the sum of all the disaster numbers. The carbon emissions data from this paper are derived from the ESS-DIVE archive, which calculates the total carbon emissions from fossil-fuel, liquid fuels, solid fuels, gas flaring, and cement production. The FDI, trade, GDP, population and other data involved in this paper are from the World Bank world development indicators database. Descriptive statistics for the main data are as follows (see Table 1):

Per capita natural capital changes (PNC) are dependent variables. Obviously, natural capital in most countries is on decline (PNC averages at -446 US dollars), ranging from -4063 to 95 dollars (natural capital growth). During the study period, there were 2,805 natural disasters in the G20, resulting in a total of 595,205 deaths. Although natural disasters occur very frequently in some countries (37 times a year), disaster occurrence averages at about 7 disasters per year. The per capita disaster total loss as a portion of GDP is 2.33E-06. The portion of affected population averages at 1.3%, ranging from 0% to 40% per year. Per capita carbon emissions are 2 tons, ranging from a minimum of 0.2 tons to a maximum of 5.5 tons.

Table 1. Descriptive Statistics of the Main Variables

Variables	Description	Mean	Median	Max	Min
PNC	Per capita natural capital changes	-446.353	-183.796	95.18482	-4062.84
FDI	Foreign direct investment/GDP	0.018915	0.015135	0.127176	-0.03623
TRD	Trade/GDP	0.4514	0.466996	1.105771	0.137531
OCC	Occurrence	7.441667	5	37	0
AFF	Total affected/population	0.013397	0.00047	0.400121	0
DAM	Total damage/GDP	2.33E-06	4.14E-07	8.21E-05	0
PCD	Per capita GDP carbon emissions	2.163402	2.146156	5.502795	0.202116
GDP	GDP growth rate	3.327656	3.225434	14.23139	-14.5311

3.2 Research method

To examine natural disasters, climate change and its impact on the natural capital, we first use panel data to analyze the modes and scales of natural disasters impact and use different natural disaster data to test the robustness of the model; then we use quantile regression to investigate the differences in the impact of different levels of natural capital wealth affected by natural disasters; finally study the extent to which natural capital growth is affected by different levels of natural disasters.

First, we consider a model as follows:

$$PNC_{it} = \alpha + \beta ND_{it} + \gamma CC_{it} + \sum \eta_i x_{it} + \varepsilon_{it} \tag{1}$$

where $PNC = PNC_t - PNC_{t-1}$, ND is the size of natural disasters measured by either DAM (-1) or AFF (-1), and CC is climate change measured by of per capita GDP carbon emissions (PCD). X is a control variable, which mainly includes foreign investment openness, trade openness, and GDP growth rate. β and γ indicate the impact of natural disasters and climate change respectively. And η and ε are the covariate vector and the error term respectively.

The above parameter panel regression model is the basic one for examining the impact of natural disasters and climate change on natural capital. Table 1 shows that there is significant heterogeneity in PNC across the G20 countries, from 95 to -4063. This PNC heterogeneity can be explained by natural disasters and climate change. We introduce a quantile panel regression model. First, we examine a model as follows:

$$PNC_{it} = \beta ND_{it} + \gamma CC_{it} + \eta_i x_{it} + \varepsilon_{it} \tag{2}$$

The quantile linear model can be expressed as:

$$PNC_{it}(\mu) = \beta ND_{it}(\varepsilon_{it}) + \gamma CC_{it}(\varepsilon_{it}) + \eta_i x_{it}(\varepsilon_{it}) \tag{3}$$

$PNC_{it}(\mu)$ is a given conditional distribution. We assume that ε_{it} is an uniform distribution conditional on ND_{it}, CC_{it} and x_{it}. To further examine the non-linear effects of natural disasters and climate change on natural capital, we establish the following semi-parametric fixed-effects panel model:

$$PNC_{it} = \alpha + f(ND_{it}) + g(CC_{it}) + \eta_i x_{it} + \varepsilon_{it} \tag{4}$$

ND_{it} and CC_{it} are added as a nonparametric variables, and they are assumed to have a non-linear effect on the dependent variable. Unobservable heterogeneity effects can be eliminated by the first-order differences. According to [33], we can derive a series of differentials to estimate:

$$P^k(ND_{it}, ND_{it-1}) = f(ND_{it}) - f(ND_{it-1}) \tag{5}$$

Among them, P^k can be estimated by a piecewise defined polynomial through knot-smoothing. The estimation of the semi-parametric fixed-effects panel model requires large sample data. As our sample includes data from 18 countries for a period of 20 years, the condition is met.

4. Empirical results

This article is focused on natural disasters, climate change and their impacts on natural capital. First, we use panel data for parameter estimation. Natural disasters in model 1 are measured by the portion of people affected. To test the robustness of the model, natural disasters in model 2 are measured by economic losses.

Table 2. the Impact of Natural Disasters and Climate Change on Natural Capital Growth

Variable	Model 1	Model 2
	-3273.8**	-3612.6**
FDI	(1698.96)	(1714.63)
	430.88***	456.06***
TRD	(127.03)	(129.43)
	23.3***	21.00***
OCC	(4.36)	(4.39)
	-19.94**	-23.48***
GDP	(8.32)	(8.33)
	-309.1***	-307.34***
PCD(-1)	(21.22)	(21.60)
	-2138.57***	
AFF(-1)	(735.06)	

	-3645680.00
Dam(-1)	(4952229.00)

The results of model 1 show that trade openness contributes to the accumulation of natural capital. With an increase in trade openness, some countries will purchase natural resource that they do not have from other countries. Thus, trade tends to reduce a country's dependence on its natural capital, and contribute to natural capital accumulation. The frequency of natural disasters contributes to the increase in natural capital. Countries subject to frequent disasters take defensive measures for protections against natural disasters, for example, using cages to raise fish instead of marine fishing and planting ecological forest instead of disafforestation. Second, post-disaster reconstruction will also mitigate the impact of natural disasters on natural capital. In addition, frequent occurrence of disasters may help a country better gain knowledge on natural disasters and this cost reduction from learning curve may contribute to the accumulation of natural capital.

FDI, economic growth and the magnitude of natural disasters measured by the amount of people affected are shown to increase the consumption of natural resources, which means they have negative impacts on environment. These results are consistent with many existing studies. FDI is often associated with production based on local natural capital, which tends to accelerate the consumption of local natural capital. The environmental pollution effects of economic growth are more obvious in developing countries such as China and India. The air pollution problems that China and India have experienced in recent years are the evidence of the negative externalities that rapid economic growth brought. Climate change is shown to have a negative effect on the accumulation of natural capital. As greenhouse gas emissions continue to rise, humans have to face the consequences such as rising sea levels, frequent extreme weather, desert degradation, and deteriorating marine ecology. They can have disastrous effects on fisheries and forest resources in natural capital.

The robustness test of model 2 shows that there is no change in the sign for all variables. Moreover, all variables in model 2 survive the 1% significance test except the variable of economic losses. This might be due to the lack of data on economic losses for quite a few countries.

4.1 Distribution of natural capital growth

Taking into consideration that the impact of natural disasters varies considerably across countries with different natural capital growth rates, we apply a fixed-effect quantile regression model into our analysis. The results are shown in Tables 3 and 4. The results of the quantile regression show that both GDP and climate change have negative impacts on natural capital growth, indicating that economic growth and carbon emissions are not conducive to environmental sustainability. An increase in trade openness positively affects countries with slow growth of natural capital, but negatively affects countries with rapid growth of natural capital. This is mainly because countries with slower growth in natural capital have to use foreign natural capital to support their economic growth. By contrast, countries with fast natural capital growth usually rely on the competitive advantage in resource endowment to export products and this strategy leads to increased consumption of natural capital.

The effect of disaster frequency on natural capitals varies across different levels of natural capital growth. At low and medium rates of natural capital growth, natural capital growth is positively correlated with disaster frequency. By contrast, at high rates of natural capital growth, natural capital growth is negatively correlated with disaster frequency. This shows that smaller disaster frequency leads to larger consumption of natural capital. And countries subject to frequent disasters are shown to have no reduction in natural capital growth. This implies that countries subject to frequent natural disasters tend to be better prepared for disasters and actively implement post-disaster reconstruction.

Table 3. Quantile Regression (AFF as the Natural Disaster)

	Quantiles			
	0.2	0.4	0.6	0.8
fdi	-3.87e+03	18.46	347.05	-1.27e+03***
	(0.18)	(0.99)	(0.29)	(0.00)
trade	362.90***	147.90***	58.18	-19.38***
	(0.18)	(0.47)	(0.27)	(0.78)
occ	7.37***	4.38***	1.04	-1.23***
	(0.31)	(0.22)	(0.22)	(0.45)
gdp	-1.08***	-8.60**	-8.42***	-6.19**
	(0.92)	(0.12)	(0.00)	(0.02)
aff	-378.41***	-22.68	-129.00***	-214.38***
	(0.86)	(0.97)	(0.00)	(0.12)
pccd	-182.68***	-121.43***	-90.28***	-68.67***
	(0.00)	(0.00)	(0.00)	(0.00)

p-values in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4. Quantile Regression (DAM as the Natural Disaster)

	Quantiles			
	0.2	0.4	0.6	0.8
fdi	871.63	-172.34	265.12	-1.11e+03**
	(0.71)	(0.00)	(0.47)	(0.00)
trade	275.11***	141.84	71.88***	-14.00***
	(0.52)	(0.00)	(0.19)	(0.00)
occ	11.06***	3.89	0.87	-2.40***
	(0.14)	(0.00)	(0.32)	(0.00)
gdp	-11.40	-8.42***	-8.2809***	-3.86***
	(0.40)	(0.00)	(0.00)	(0.00)
dam	4.92e+06	8.40e+05	-1.10e+04	-1.56e+06
	(0.71)	(0.00)	(0.976)	(0.12)
pccd	-441.41***	-117.39	-89.00***	-69.78
	(0.00)	(0.00)	(0.00)	(0.00)

4.2 Semi-parametric panel regression model

Then we use the semi-parametric panel regression model to examine the relationship between natural capital growth and different disaster parameters. Figures 3 and 4 describe the relationship between natural capital growth and two different natural disasters respectively. Unlike parametric analysis, the semiparametric panel regression model primarily identifies nonlinear relationships. Like the magnitude of natural disasters, the growth rate of natural capital varies across G20 countries. There is an inverted U-shaped relationship between the growth rate of natural capital and the magnitude of natural disasters. For small disasters, natural capital growth is not affected much. But for large disasters, growth rate in natural capital falls rapidly. This is the same as the result of the quantile regression on GDP and natural capital growth.

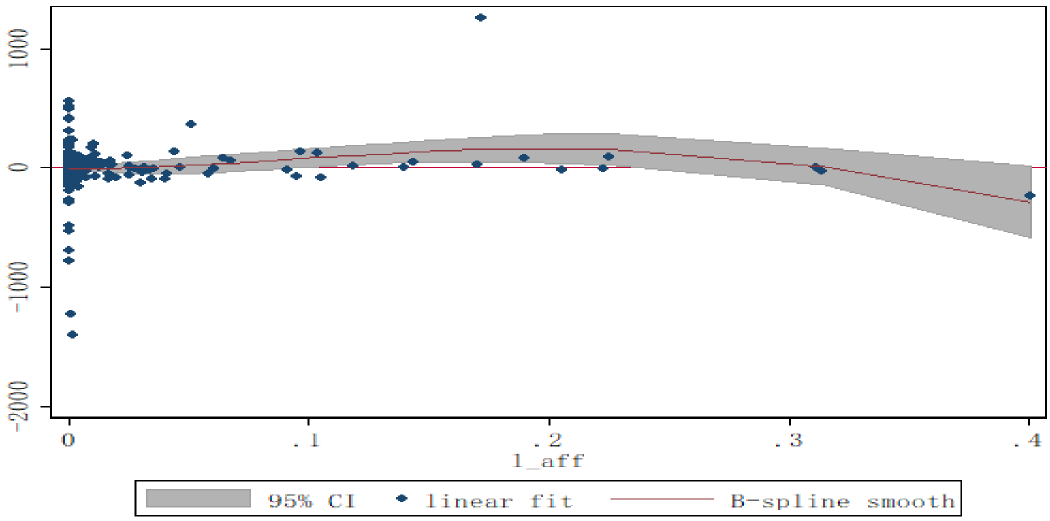

Figure 3. Natural Capital Growth and Natural Disasters (Affected)

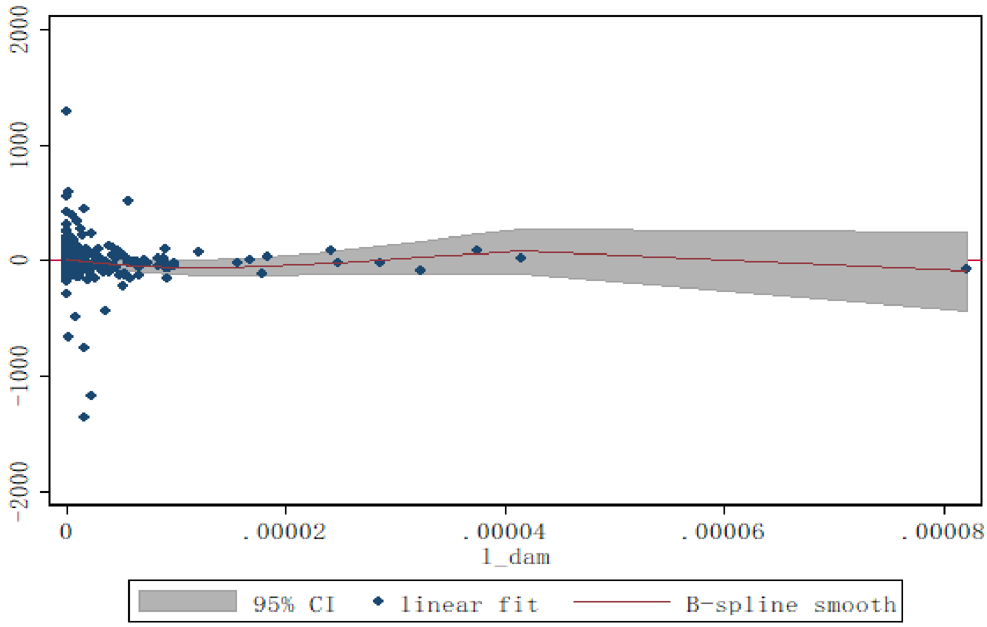

Figure 4. Natural Capital Growth and Natural Disasters (Damage)

5. Conclusions and discussions

The economic impacts of natural disasters and climate change have been growing for the past few decades. This has led to an attempt to understand their impacts in hope of better policy recommendations to mitigate the losses of disasters. So far, there is abundant research literature on the impacts of natural disasters on economic growth, but little has been done on natural disasters in relation with natural capital stock that are essential for sustainable development. This paper seeks to contribute to literature in this research line. We take G20 countries as a sample to examine the impact of natural disasters and climate change on the natural capital component of inclusive wealth. First, we used panel data to examine the impact of natural disasters, climate change, and other relevant factors on natural capital growth. Secondly, the model robustness is tested by using different natural disaster variables as surrogate indicators. In addition, we also used the quantile regression model to examine the differences in the impact of different natural capital growth on natural disasters and climate change. Finally, the semi-parametric model was used to examine the extent of the impact of the disaster.

Our study shows that trade openness and natural disaster frequency contribute to the accumulation of natural capital in G20 countries. Trade openness leads to the use of foreign natural resources reducing the consumption of natural capital. Increase in disaster frequency may help countries with disaster prevention mechanisms and disaster prevention knowledge, all of which are conducive to reducing the adverse impact of natural disasters on natural capital. FDI, GDP growth, climate change and the amount of people affected by disasters are not conducive to natural capital growth. This shows that the economic growth of G20 countries might not be environment friendly, which threatens the long-term sustainable development of the economy; the results of quantile regression show that GDP and climate change are not conducive to natural capital growth, regardless of scale. The increase in trade openness is more conducive to countries with slower growth of natural capital, and is not conducive to countries with faster growth of natural capital. The countries with frequent disasters are shown to have no decline in natural capital. The results of the semi-parametric panel regression model show that there is an inverted U-shaped relationship between the growth rate of natural capital and the size of disasters. For small disasters, natural capital growth is not affected much. But for large disasters, natural capital will fall rapidly.

Based on the above research, G 20 countries are advised to do the following to achieve sustained growth of inclusive wealth. First of all, efficient use of natural capital is the foundation for the sustainable growth of natural capital. This means that even if non-renewable natural capital such as fossil fuels is available in abundance, countries should follow the Hartwick Rule. This means using natural capitals efficiently and investing their profits in infrastructure, education, health and the development of renewable natural capital for a lower risk of carbon exposure and more diversified economic structure. G20 countries should understand that using natural resources for short-term gains and economic growth would sacrifice long-term sustainability and future growth. Second, the impact of natural disasters and climate change on sustainable development must be considered for a better management of sustainable natural capital. For example, it is necessary to develop regular preventive measures for small and medium-sized natural disasters. For large natural disasters, emphasis should be placed on emergency plan. In addition, given the impact of trade openness and FDI on a country's inclusive wealth, cooperation between countries is needed to jointly address the impact of climate change on sustainable development. In particular the experience and technology from developed countries should be better used by developing countries to reduce the impacts of climate change including numbers of deaths and economic losses.

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