An analysis of the economic costs of natural disasters in the Philippines - does the natural disaster type matter?

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Abstract

Ranked as the most disaster prone country in the world by the World Risk Index, the people of the Philippines have had their fair share of natural disasters and will probably continue to be affected by them in the future. With the help of The International Disaster Database the purpose of this paper is to analyze if the actual type of natural disaster has an impact on the total direct economic damage done. I will then continue with an analysis on why this might be the case and then conclude with a discussion about potential areas that could be improved to mitigate these costs in the future using the Disaster Risk Index.

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1. Introduction

Each and every year millions of people are affected by natural disasters causing great damage to the welfare of humanity all around the world. One country that is especially impacted by natural disasters is the Philippines. The location in the pacific makes it so that typhoons and floods are a common occurrence with an estimate of about twenty typhoons hitting the country on average each year. Earthquakes and volcanic activity is also a regular event in the country due to the fact that it is located on top of the pacific ring of fire, giving rise to 24 active volcanoes in the country (PHIVOLCS, 2023). The geography and location of the country makes it very prone to natural disasters and this together with the fact that 3/4 of the population is living in areas in direct danger of natural disasters makes it so that the impact on the country becomes so much bigger (Climate Change Knowledge Portal, 2021). Just in the time period of 2010-2019 the costs from natural disasters is estimated to almost 500 billion philippine pesos (PHP) or about 9 billion USD (Philippine Statistics Authority, 2020). In 2013 one of the strongest typhoons ever recorded struck the country causing an estimated cost of 100 billion pesos and the deaths of seven thousand people.

The total damage is usually estimated through direct and observable things from the immediate impact of these disasters such as in the form of damaged or destroyed buildings and infrastructure together with injuries and death. But due to the variety in the type of disasters one might think that some are more costly than the others, especially the ones that are more sudden and unpredictable such as earthquakes and volcanic eruptions since the people and government cannot prepare themselves as good as they could if they would have knowledge that a natural disaster is about to happen like it usually is in the case of typhoons and droughts.

But the economic costs of disaster and the immediate human impact is not the only problem, another side of the issue is secondary effects. Severe disaster events can even lead to major disruptions of the supply of necessities such as food and water and people might lose jobs due to the destruction of farms or capital, which then leads to a further deterioration of the affected people in the forms of unemployment and poverty. All of these things have a detrimental impact on the welfare of people and the society as a whole. Due to the fact that there are so many different types of disasters and some more unpredictable than others it becomes difficult to decide which investments should be made to mitigate the costs. Since so many people in the country is affected by it and there is no indication that it will stop it becomes important to try and understand what type of natural disaster actually leads to the higher costs. With this understanding both governments and people can make informed decisions regarding areas of investments that target the type of disaster that cause the most damage so that there can be a mitigation or removal of the cost of a disaster in the future, and to increase the overall wellbeing of the people.

1.1 The purpose of the study

The main purpose of this study is to analyze and understand if the type of natural disaster has an impact on the economic costs to the society, once this has been established further analysis will be made to try and explain why this is the case. The study will then conclude with a discussion about how we can try to mitigate these costs in the future. The purpose of the study can be concretized in the form of three questions:

I. Does the type of natural disaster affect the amount of economic damage?
II. Why does this type of natural disaster lead to the higher costs?
III. Are there improvements that can be done to reduce the costs?

The main goal is to determine if there is a difference in the total economic damage done depending on what type of natural disaster it is. The two other questions are secondary but follow the further analysis that will be done after the main one has been established, namely an analysis of what the theory says about this type of disaster and if it is possible to mitigate the costs from future events. At the end of the study my hope is to be able to reflect on these questions again and be able to answer them or at least attempt to with a better understanding of the underlying factors.

1.2 Disposition

The disposition of the study is as follows, the second chapter will provide background information about the country and natural disasters that are especially relevant to the Philippines. The first part of the third chapter will introduce the reader to how natural disaster impact the overall economy, the second part of this chapter will then discuss previous research on the topic of different natural disaster types and their relationship with the total cost. Chapter four will discuss the methodology and what kind of data that will be used. Chapter five will start off with a presentation of the results and the second part of the chapter will be reserved for the discussion. The final chapter will be a summary and a conclusion to the study.

2. Background and theory

The objective of the second chapter is to give a brief introduction to the Philippines and thus create an overview and picture of the country, this is then followed by information about disaster risk and climate shocks. The chapter is then concluded with a review of the theory on natural disasters impact on the country.

2.1 The Philippines

The Philippines is a country located in Southeast Asia close to the equator, consisting of over 7640 islands creating a massive archipelago. Even though the country includes such a big amount of islands it is only the ten largest ones that account for about 95% of the total area of the country. The great amount of islands can be seen as forming three larger groups of islands and these are named Luzon to the north, Visayas in the center and Mindanao in the south (Encyclopedia Britannica, 2023).

The country is completely surrounded by oceans which makes the country the complete opposite of landlocked. Furthermore the climate of The Philippines is a tropical one with two main seasons, the rainy wet season between June and November and the dry season between December and May. This is accompanied by a high temperature all year round, humidity and a great amount of rainfall (Encyclopedia Britannica, 2023). The archipelago has different levels of elevation across the country with some parts such as in the north being surrounded by a mountainous landscape. This then leads to a variable amount of rainfall depending on location in the country (Climate Change Knowledge Portal, 2021).

The poverty rate in the country is quite high leading to the government actively working to reduce it but the recent covid pandemic was accompanied by an increase in the poverty rate and thus undermining the efforts by the government (The World Bank, 2022) . Reports from the World Bank and the official government sources presents this number as sitting at around 18% of the total population for 2021 equating to about 20 million people (Philippines Statistical Authority, 2022). With the current situation and unrest around the world the inflation is also high and most countries are suffering like The Philippines from a higher rate of inflation well above the target. Most countries strive to have an inflation target range for the purpose of being able to keep the change in price level stable and predictable, reducing uncertainty, anchoring inflation expectations in the population and thus fostering and promoting a sustainable growth. For the central bank in The Philippines, Bangko Sentral ng Pilipinas (BSP) the target range is around three percent plus and minus one percent. Reports published by official government sources indicates an inflation rate of about 8.6% in early 2023 (Philippines Statistics Authority, 2023a), falling from an almost fifteen year peak point of 8.7% at the start of the year.

The economy in The Philippines is largely driven by the sector for services which accounted for 61% of total GDP in 2021, followed by the industry sector with 29% and agriculture with 10 % (Statista, 2023). The sector for services also employs the majority of the labor force in the country with 61% of the total employment. The second largest sector in percent of total employment is not the industry sector but it is instead the agricultural sector with about 22% of the total employed people (Philippine Statistics Authority, 2023b). Even though the output of the agricultural sector today is quite low relative to the industry sector there are still more people employed in agriculture and it shows that it is still a central part of many people lives.

A growing population together with urbanization seems to have led to less people living in rural areas and less land being used for agricultural means, an effect also amplified by the changing climate and natural disasters. At one point in time this sector was responsible for employment of almost half of the total employment in the country (The World Bank, 2021a). Recently the trend has been falling but the sector still remains one of the biggest and most important sector of their economy. Agriculture in itself has always been an important part of The Philippines throughout history not only in the economy but also for the population, because of the landscape and climate leading to good conditions for crops. Many parts of the country was previously filled with land and forests suitable for agriculture which led to a majority of people living in rural areas. Data suggests that for some time periods more than 70% of the population lived in rural areas and thus relied on agriculture to feed themselves and their families (The World Bank, 2021b).

About 24% of the country is covered in forest and together with the fact that the whole country is surrounded by ocean makes it so that forest and fishery also becomes an important part of the economy and day to day life of many people. All of these sectors are highly susceptible to any disturbances in the climate or natural disasters, with temperature changes possibly leading to crops being pushed out from some areas or rising sea temperatures leading to changes in the ecosystem and less fish. Because of this, relief in the form of prevention, support and rehabilitation after an event has become an important part for the local governments, one of these requirements is that 5% of the revenues in the municipality is used to create a disaster relief fund that can be used if there is a disaster event (Official Gazette, 1991).

2.2 Disaster risk index

In order to assess the disaster risk for different countries and to increase awareness a model needs to be created that can capture the different factors that contribute to the risk, one model that has been created is the WorldRiskIndex created jointly by the United Nations University and Bündnis Entwicklung Hilt. Each year the individual disaster risk of natural disasters and climate shocks is estimated for each of the 193 member countries in the United Nations using the model developed by the United Nations University Institute for Environment and Human Security. This is the foundation of the World Risk Index that is then published annually in the World Risk Report in order to be able to give a global overview and increase awareness of these risks. The annual World Risk Report for 2022 was published by Bündnis Entwicklung Hilt and the Institute for International Law of Peace and Armed Conflict in Ruhr University Bochum.

The index is built upon two central pillars, *exposure* and *vulnerability,* vulnerability is then further divided intro three factors - susceptibility, coping capacities and adaptive capacities. Exposure can be seen as the factors that are outside of the control of humans, with the magnitude and frequency of events happening directly impacting the amount of exposure. Vulnerability captures the societal side of the risk which humans can impact. Exposure score is dependent on frequency and intensity of the natural disasters with a higher score indicating more frequent or bigger magnitude of events impacting the society. Vulnerability score shows how easy societies can be destroyed or destabilized. Susceptibility as a part of vulnerability shows how the structural part of society such as poverty amplifies or lowers the effects of a disasters. Coping capacities shows how well the society can rebuild, mitigate and handle the situation after an event has already taken place. And lastly the adaptive capacities is meant to capture how well the society can adapt, change and be proactive to prevent the negative effects before an event occurs (Bündnis Entwicklung Hilft, 2022).

After all the individual scores has been calculated there is an aggregate done and the final score is presented as a value sitting between 0-100 so that comparisons can be made between countries. A combination of very high exposure together with high vulnerability leads to the latest report ranking The Philippines as the number one country with the highest disaster risk. The important thing to understand is that the disaster risk index is composed of both exposure and vulnerability. While the frequency and intensity of natural disasters cannot really be affected the other part of the disaster risk, vulnerability is something that we can affect and improve upon.

2.3 Climate

The climate in itself has a big effect on humans and countries everywhere, sudden and unpredictable changes could lead to disasters such as extreme heat, reduction in water supply or quality of water and rising sea levels. All of these leads to a reduction in the human welfare and health (CDC, 2022). Extreme heat could lead to an increase in heat related illness and wildfires. In some cases reduction in the amount of expected levels of rainfall could lead to droughts that would negatively impact water supply and put a strain on humans trying to survive but also everything else that needs water such as agriculture, livestock and plants. Rising sea levels are a major concern especially for The Philippines (PAGASA, 2023a) since it is surrounded by water and any change in the level of sea water would have immediate impacts, such as flooding displacing the people that live close to the shore .

As briefly discussed prior the tropical climate of The Philippines is one factor contributing to the flourishing of the agricultural sector, with high levels of rainfall combined with a massive amount of fertile soil creating the perfect agricultural landscape. This paper will mention climate shocks, these can be seen as a temporary shock/deviation from the equilibrium level or the average of example sea water temperature.

From the facts established earlier it is quite apparent that any kind of climate shock that has an impact on the Philippines will have an impact on the wellbeing of the people but it will also have an impact on the agricultural side of the country and thus the economy. The agricultural side of the economy is especially sensitive to changes in both temperature and the amount of rainfall. One phenomenon that has a big impact on the country and especially on some forms of natural disasters is the so called El Niño-La Niña Southern Oscillation (ENSO). This climate shock manifests itself as a fluctuation of the sea temperature around The Philippines directly impacting the amount of rainfall (Hilario, De Guzman, Ortega, Hayman, Alexander, 2009). During the hot phase the temperature of the sea increases and it is referred to as El Niño. During the cold phase the opposite happens and the temperature falls, this colder phase is referred to as La Niña. The inflationary impact of ENSO was also established by Arcenas (2018) where he found that there was significant impact on the overall price level in the Philippines during ENSO events.

2.4 Natural Disasters

Natural disasters in this paper can be classified as any natural event that leads to great amount of damage to the society such as loss of life or the economy in the form of damages to infrastructure, buildings and agriculture. The impact and downward spiral of effects natural disasters can have on the Philippines is analyzed thoroughly by Benson (1997). The immediate effect on humans is loss of life or injuries. Any destruction done to buildings or agriculture could lead to secondary effects of people becoming homeless or losing their income. Another thing to think about is that the destruction can also lead to shortages in houses and crops leading to inflationary pressure. If there is destruction of infrastructure such as roads then there might be a shortage in the food supply caused by the fact that people are just unable to deliver the crops or food.

The most relevant natural disasters in The Philippines are earthquakes, droughts, floods, typhoons and volcanic activity. The country is located on the so called pacific typhoon belt which leads to an anticipation of being hit by typhoons every year. Not only does the country reside atop the typhoon belt but also the pacific ring of fire, this ring goes around the edges of the pacific ocean and the whole country is situated on top of it. The characteristics of this ring is a massive amount of volcanic activity together with earthquakes. Three fourths of all volcanoes on earth are situated on the belt and together with the fact that 90% of all earthquakes on earth also occur on this ring (National Geographic, 2022) makes it so that the whole area becomes very dangerous.

Below a stacked bar chart with is presented showing the frequency of the five selected types of disasters between 1990-2022. In the period that is presented the most frequent ones sorted in order are typhoons, floods, earthquakes, volcanic activity and in last place droughts.

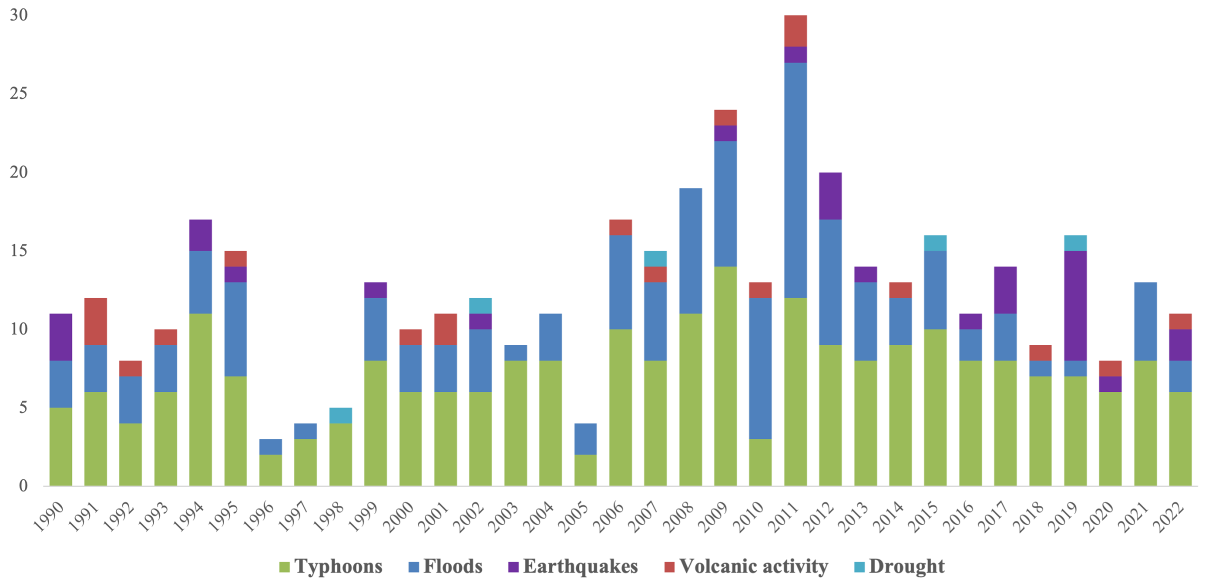

Figure 1. *Chart showing the frequency of various disasters 1990-2022. Source: EM-DAT*

As can be observed from the chart, there is quite a variation in both frequency and type of disaster events over the years. Another thing that can be observed is that every year since 1990 has had at least one typhoon event and majority of the years even showing multiple events. There were also floods every single year except for the years 1998 and 2020. To get a better understanding of how different types of natural disasters impact the country lets take a closer look at them individually.

2.4.1 Earthquakes

Earthquakes might seem like they don't happen that often looking at the chart but in the EM-DAT dataset that was used to create the chart only earthquakes of a magnitude greater than six were included so the actual total amount of earthquakes that happen in the country is much higher. One explanation for the frequent occurrence of earthquakes is activity by tectonic plates under the country, the geology under the country is quite complex but to put it briefly the country is situated on top of tectonic plates that has been compressed by other plates which has the effect of pushing upwards on the land above in some parts, this also leads to formation of trenches surrounding the country. This is called the Philippines mobile belt. The continued activity of these plates lead to regular smaller magnitude earthquakes happening. At the same time the country is situated on the pacific ring of fire which is home to 90% of all earthquakes on the planet which gives another explanation for the big frequency in the amount of earthquakes.

When thinking about earthquakes the first things that come to mind are the immediate effects to society, there can be severe loss of life, damages to buildings and infrastructure. The nature of this event makes it so that it is not really possible to prepare since it is so unpredictable and can happen anytime, this would probably increase the total costs since people are just less prepared. But depending on the magnitude of the earthquake there can be secondary effects (Daniell, Schaefer & Wenzel, 2017) such as landslides, rockfall and the most serious ones - tsunamis and volcanic eruptions. The secondary effects could lead to amplifying the damages done to life, infrastructure and buildings. Due to the fact that the country is completely surrounded by water makes it so that the risk for tsunamis after an earthquake is very high. If disaster relief is initiated after the earthquake there also has to be a concern for tsunamis or volcanic activity which could strain or hamper the relief effort.

Looking at the dataset from both EM-DAT (EmDat, 2023) and the Natural Centers for Environmental Information it can be seen that volcanic eruptions following an earthquake is rare with it only happening once in a hundred year period compromising hundred earthquakes. Tsunamis after an earthquake happens more often, in the same period that was used to look for volcanic eruptions there was about a 40% chance of a tsunami event after an earthquake but if we only consider the most recent twenty years the amount of tsunamis after earthquakes fall to about a 12.5% incident rate.

It is important to understand these potential secondary effects since even if the earthquake in itself does not really amount to a high amount of damage the follow up effects of a tsunami or volcano could have a significant impact on society and cause great economic costs.

2.4.2 Droughts

When the amount of rainfall in an area is way below normal this could cause a shortage of water, this shortage would then lead to a sustained period of dryness in an area causing a drought. Droughts are the most rare event in the chart that is presented with only five occurrences. Climate shocks such as ENSO has a quite big impact on these drought events as established by Hilario et al. 2009 since they impact the amount of rainfall in affected areas. The droughts are mainly due to the effects of the hot phase El Niño with four out of the five droughts happening when there was a long and sustained El Niño event which caused a drier than normal environment in some areas (EmDat, 2023).

Droughts don’t usually have an impact on buildings and infrastructure but the effect on the welfare of people is quite apparent. A normal human cannot live long without water so a sustained shortage of water over a long period will cause great harm. If the drought is in an agricultural area then the economic loss could be massive since then both farm crops and livestock are also affected. For the people living in the affected areas that sustain themselves on the food they gain from farming will now not only have a water shortage but also food shortage causing even more problems. If the farmers instead produce food to nearby societies then the supply of food to multiple people are also hampered. A drought in a specific area could then be seen as having far reaching effects depending on how much food is also produced from the area. Unless there is sustained aid provided to the affected areas until the drought is over the only option is to try to move away from the area, an option that is not really viable for the poor people.

When we compare these type of events to earthquakes it is not as unpredictable and not just something that happens suddenly. These type of events that are affected by the climate can be monitored and warnings can be given to the areas that will be affected by the drought, this makes it so that people are prepared and thus likely lowers the economic costs.

2.4.3 Floods

While droughts are due to the effects of a lack of rainfall floods can be seen as the opposite extreme end with a prolonged period of too much rainfall. Other disasters could also lead to floods such as tsunamis, earthquakes causing land to sink and landslides and rockfall from the hills which could cause damage to rivers or dams leading to floods (PAGASA, 2023b). They happen quite often in the country with an event happening every single year in the chart except for 1998 and 2020.

Floods being such a regular occurrence in the country is quite alarming since even small floods can cause a great amount of damage to agriculture and infrastructure. And due to the properties of water floods spread easily. While droughts mainly disrupted the agricultural side in the economy floods could potentially disrupt every single sector. Big floods could lead to massive forced displacement or loss of lives in whole towns and cities. Similar to droughts floods could also lead to shortages in food if the flooding affect an agricultural area and it could have permanent effects if the flooding leads to erosion of the soil that is used for crops. It could also have an effect on the water supply since flooding will most of the time contaminate the ground water supply (PAGASA, 2023b).

Another aspect of this kind of disaster is to take into account that not everyone in the country knows how to swim. In a working paper by Borgonovi, Seitz, and Vogel (2022) published by OECD on the topic of swimming skills around the world it is shown that only about 50% of people over the age of fifteen are able to swim without a form of assistance in the country. So a flooding that affects an inhabited area could have disastrous effects. With this in mind it increases the probability of drownings during a flooding event, this increases the severity and costs to society that a flooding might have on the country compared to if the percent of people that could swim was higher.

Similar to droughts floods are not really something that just happens at a snap of a finger, floods are mainly caused by rain which then depending on the intensity will take some time to actually form floods if it even happens at all, this would probably also limit the economic cost in a similar way as a drought since the affected people could prepare for when they know it will be a wet rainy season and then adapt when it occurs.

2.4.4 Typhoons and storms

Typhoons are by far the most frequent disaster event in the country with multiple typhoons hitting the country every single year. A typhoon can be seen as a tropical cyclone with thunderstorms and strong winds rotating in a spiral around a center called the eye. The formation of these cyclones are usually in seven distinct part of the world with the area that affects the Philippines the most being the northwestern pacific ocean, cyclones formed in this area is referred to as typhoons.

The deadliest typhoon to affect the country in the last hundred years was typhoon Haiyan or locally known as super typhoon Yolanda. This typhoon devastated the country when it made landfall in 2013 affecting over 16 million people and leading to the deaths of at least 7000 (EmDat, 2023). The effects of typhoons come in the form of massive amounts of rainfall, very intense sustained wind speeds with some typhoons reaching 290+ kilometers per hour and storm surges leading to tsunami-like conditions. Most of the time these effects lead to flooding which the strong winds then amplifies and can hinder the relief efforts.

Since the effects of flooding has already been discussed this part will focus on the strong winds and storm surges that are accompanied by typhoons. The storm surges due to typhoons have a big impact on the coastal areas, storm surges can lead to tsunami-like conditions with a destructive force magnified due to the extreme wind speeds which can then lead to destruction of houses, infrastructure and even deaths (PAGASA, 2023c). The strong winds from the typhoons also lead to destructive power but there might also be another effect of the strong winds in the form of hampering the relief efforts. Due to the destruction of infrastructure usually caused by natural disasters one way of trying to provide aid to the affected would be to use helicopters since these are not affected by the destruction or blocking of roads. But due to the extreme wind speeds this is not really possible and the relief efforts can be delayed causing even more damage to society.

2.4.5 Volcanic activity

In the data set that is used for the chart volcanic activity does not only refer to volcanic eruptions with lava flow but also ash-fall events. The most recent volcanic eruption in the country was the Taal volcano in 2022, the same volcano has also had eruptions in 2021 and 2020. The Philippine Institute of Volcanology and Seismology classifies an active volcano as a volcano that has had an eruption in the last 600 years. Using this classification there are 24 active volcanoes in The Philippines at this moment (PHIVOLCS, 2023). Most of the volcanoes are located around three clusters, the north east, east and southern parts of the country which makes it so that these areas are especially affected by volcanic activity.

Ash-fall occurs when very small particles of volcanic debris gets ejected from volcanoes that can then linger in the atmosphere. The effects of ash-fall on humans is not as severe as the other natural disasters but it might still lead to the air quality diminishing and inhalation could then lead to problems in the airways and overall health. One sector that feels the economic impact is the aviation around the area with ash-fall, the ash-fall could lead to engine damage and the reduction of visibility in the air leading to major disruptions to both aircraft and airports.

Eruption events are a different type of volcanic activity that is considered more dangerous than ash-fall events. While ash-fall is an ejection of small particles an eruption event could lead to ejection of rocks, lava and dangerous gases. All of these would have a severe impact on the people living in the area affected by the volcano. Lava being ejected could lead to destruction of buildings, farm lands and it could lead to wildfires spreading causing even more damage. The Center for Disease Control and Prevention (CDC) note that the gases usually rapidly gets taken away by the wind but some toxic gases that are heavier could become trapped in low elevation areas, close to the sea level (CDC, 2022). This becomes a problem in the country since there is such a variable landscape of hills, mountains and elevation.

The rocks that get ejected out from the volcano will also have destructive power, very large rocks could lead to big destruction of everything in the area of impact and depending on how far they get ejected people and buildings not in the immediate vicinity of the volcano could still become affected. Volcanic eruptions fall under the same kind of problems associated with earthquakes in that they are more on the unpredictable side. This would probably be an indicator that the economic costs associated with these type of events are higher.

To summarize, this chapter gave us an overview of the current situation in the Philippines and the Disaster Risk Index. The last part of the chapter gave us an understanding about how each of the different disaster types can lead to big damages to society and how there are variability in both the destructive power and the predictability of these events. This makes it so that people can be more prepared for some of the events which should have an impact on how much the different type of events affect the total economic cost, if the amount of affected people is the same. The chapter is concluded with a figure to visualize which sectors of the country that receives the highest annual economic costs. With the most prominent over time being the agricultural side. The chart shows damage in millions of philippine pesos (PHP).

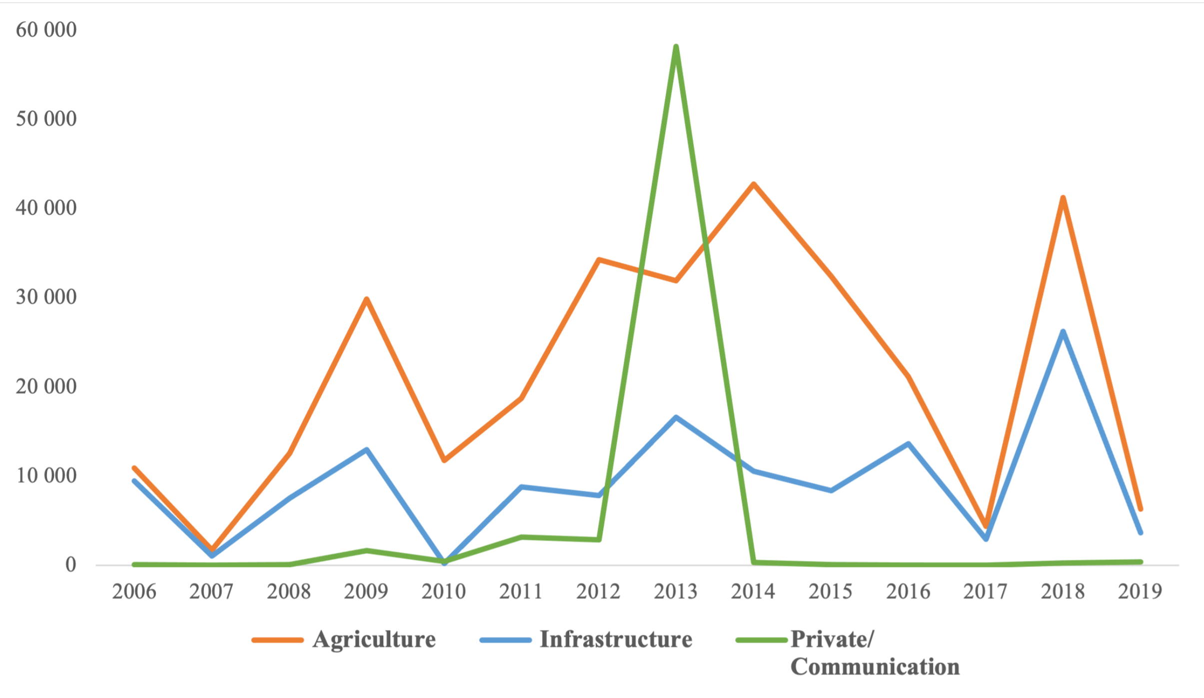

Figure 2. *Graph showing annual costs to various sides of the economy due to natural disasters in the period 2006-2019 in millions (PHP). Source: Philippine Statistics Authority.*

3. Previous research

This part of the paper is divided into two parts, first an overview of previous studies on the impact of natural disasters on the overall economy will be presented. In the second part previous studies relating to the economic costs associated with natural disasters will be discussed. The purpose of this is to first gain an understanding of the relationship between the economy and natural disasters and then once the relationship has been established - dive deeper into the specific costs associated with the different types of natural disasters.

3.1 Overall impact on the economy

There has been some former studies on the effect natural disasters has had on The Philippines overall economy, such studies has mainly focused on the impact on GDP and the theory of creative destruction. A possible positive effect of natural disasters on the economy in the form of creative destruction is interesting to think about because if it holds and the positive impacts outweighs the negative costs then the views on natural disasters as a fully negative and disruptive one to society can become challenged. The topic of creative destruction in the aftermath of disasters in The Philippines was explored by Jha, Quising, Ardaniel, Martinez and Wang (2018) where the rebuilding and restoration after an event presents an opportunity for innovation to improve old capital and systems. The researchers then link this to the creative destruction hypothesis that states that there needs to be a destruction of old processes and capital to make way for new innovation. The main idea behind this in the context of the Philippines is that the costs associated with replacement of the old capital with newer ones after a disaster could be cheaper than repairing the old ones.

On the topic of creative destruction there could perhaps be a positive hidden effect that is not accounted for when the economic cost is measured during the natural disaster. When the measurement of total economic damages done by disasters is done in the aftermath of an event it is usually in the form of direct observable damage such as loss of lives, damage to buildings and infrastructure. But if there is also evidence that disaster events can lead to a positive effect on the economy in the periods following the event then the measurement of economic cost might need to be revisited to account for these effects. In the paper it is noted that it is difficult to predict how the growth trend will behave after an event, it may fall under the historical trend if there are difficulties in replacing lost capital and infrastructure but the growth trend may also find itself being above the historical trend if the replacement for the old capital ends up being more productive and thus contributing more to society than the old ones.

The study by Jha et al. (2018) also shows that in areas affected by typhoons there is a higher chance for people outside of poverty to be brought down into poverty and people already living poverty has a higher chance of falling even further down in poverty. All of this could lead to further economic costs in the future that is not accounted for by the total direct damage. The result is also understandable since the people in poverty are the ones that are most likely forced to have to settle in high risk areas due to poverty and have the least amount of resilience both due to their economic situation and the quality of housing.

No matter what the economic outcome is in the aftermath the immediate effects of natural disasters on the people in poverty or on the brink of it will be significant, since the poverty itself is reflected in the quality of housing and location they settle in as discussed by Narsey Lal, Singh and Holland (2009). In the short term their houses may be destroyed together with the farmlands they use to gather food, this together with the possibility of a negative effect on the food supply pushing prices up will just push these societies even deeper down the hole of poverty. If there is no financial aid received or it is not adequate then it might just lead to even poorer quality of housing or no housing at all and the cost of restoring the farmlands might not even be possible, permanently limiting the supply of food that can be produced by these people. This may lead to a vicious negative cycle where the people in poverty keep getting affected by natural disasters over and over and thus remain in poverty.

In another paper Bringas, Bunyi and Manapat (2022) attempts to determine impact of natural disasters on the Philippines economy, in this paper they use GDP per capita as a response variable with natural disasters and foreign direct investment as explanatory variables. It is noted that research on the long run effects of natural disasters on the economy has been very scarce and thus the researchers aim to provide insight into this topic by using data from The Philippines. The study by Bringas et al. (2022) shows that for the short run every variable had a negative impact on the GDP per capita. Each form of natural disaster such as flooding, earthquakes and storms had a negative coefficient but with different magnitudes, showing that the impact in the short run is dependent on the type of natural disaster. It is also noted that in the short term directly after an event most developing countries do not really focus on long term resilience in the form of upgrading capital to improve productivity or better technology to be more resilient for future events but the focus is instead on short term recovery for the people affected.

If we then go back to the theory of creative destruction, the results from Bringas et al. (2022) concerning the impact of natural disasters on GDP per capita does not really support the creative destruction theory. It instead seems like the opposite effect with a slowdown of economic activity and natural disasters having a negative effect on the economy in the short run. Supported by the fact that each of the variables for the natural disasters had a negative coefficient, with each one lowering the GDP per capita and thus the productivity per person. In the long term however foreign direct investment was the only variable with a positive effect on the GDP per capita and it could perhaps be that the creative destruction has some merit in The Philippines if the influx of foreign investment is directly linked to the rebuilding and rehabilitation in the aftermath of an event and that these investments then also lead to better and more efficient productivity.

3.2 Economic cost of different disasters

There are not really any studies that tries to determine if the type of disaster has an effect on the total cost in the Philippines or in general. Most studies on the costs of natural disasters in the forms of direct damage usually test if the level of income in the form of GDP per capita has an impact on the total cost. For climatic disasters that are relevant to the Philippines such as windstorms and floods Kellenberg and Mobarak (2008) found that these type of disasters has a positive relationship between the total economic cost of the disasters and the level of income measured in GDP per capita up to a certain point. The study showed that the relationship might not be linear with the total cost falling after reaching a specific level of GDP per capita. The explanation they offer is that at lower income levels most of the income for people is spent on necessities to survive and the proportion of income that can be spent on other things to mitigate the costs of a disaster is relatively low. Once the income level reaches the higher levels more money can be used on disaster mitigation efforts that reduce the costs once a disaster happens (Kellenberg & Mobarak, 2008).

This is a very interesting insight to think about as it seems to indicate that differences in the economic cost of different type of disasters is also dependent on the income level of the country and that the relationship might have some form of non linearity to it. If the economic costs only fall after a threshold then it could be that developing countries with lower incomes do not reach this due to the positive effects natural disasters also had on poverty as previously noted. If both total costs and poverty increases in the aftermath of natural disasters, the level of income that leads to reduction in the costs might never be met and it will lead to a continuous negative cycle where the people affected become stuck in poverty and cannot reach the income level required to be able to invest in disaster cost mitigation.

Schumaker and Strobl (2011) explores a similar topic but incorporates the exposure risk of countries to natural disasters into their model. For countries that have low exposure risk they also find that the relationship between income level and economic loss from disasters is non linear with increases in costs until it hits a plateau to then start falling like the previous study. But they also find that the same form of relationship does not hold for countries with high exposure risk. For these countries the relationship between costs from natural disasters and income level seems to be inverted with falling costs from disasters as level of income increases until it bottoms out to then start to increase again. Another thing that is established from the paper is that the u-shape relationship between economic costs and level of income is flatter the higher the disaster exposure risk is for the country, this indicates that the most disaster prone countries in the world such as the Philippines will have a decreased level of economic cost and rate of change when the income level increases past the lowest point in the u-shape, compared to a country with a lower exposure risk but same income level.

4. Data and Methodology

This part of the paper will first present the data that has been used throughout the paper and will continue to be used in the model and analysis. Once the data has been presented an overview of the methodology will continue in the second part of the chapter.

4.1 Data

The data that is used throughout the paper is from the Emergency Events Database (EM-DAT) provided by The Centre for Research on the Epidemiology of Disasters from UCLouvain Brussels. This is a database updated daily that contains information about disaster events from the 1900 all the way to the present 2023 compiling the information from multiple sources such as, UN agencies, NGOs and research institutions. In the database each disaster is also accompanied by data on the magnitude of the disaster, the human impact with deaths, injuries and total number of affected. Economic impacts of the events are also available with data on the amount of monetary aid received in the aftermath of events from the UN coordination of humanitarian affairs. Also provided is estimates of total economic damage, damages covered by insurance and the costs for reconstruction, the economic data has been adjusted for inflation using the CPI and 2022 as a base year. This makes it so the total damages done can be compared between the wide range of years.

The database of choice that is used in majority of the studies that also cover natural disasters is the EM-DAT database and this together with the type of data that is provided in the data set makes it an excellent choice for this paper as well to determine which type of natural disaster has the biggest impact on the total cost. However there are some limitations with the data, the criteria used to determine the inclusion into the database is, at least ten deaths, at least one hundred total affected, government declares emergency or government calls for international help. If one of these criteria is met then the event will be included in the database. This means that there are some events that are missed in the database even if the economic cost is quite high just due to the fact that it only affected a small amount of people. Another issue lies in the fact that the total cost for a disaster is not used in the criteria for inclusion, due to this not every disaster will have a value for the economic loss estimated which will lead to only a smaller set of observations being usable in my analysis.

Another limitation is in the actual estimation of the total economic damages, the fact that is is difficult to actually quantify the indirect and secondary effects of natural disasters will lead to the estimate of the total damage done only capturing the direct effects and thus underestimating the actual total costs in society, which are highly probable to be much higher.

4.2 Method and model

To determine which disaster event has the most economic impact a model that can capture this relationship needs to be specified. Due to the nature of the EM-DAT data that will be used it seems like an OLS multiple regression would be a good choice. The general form for the regression with n variables will be:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon$$

Where (Y) is the dependent variable, the various betas (β) are constant and show the expected change in (Y) when we increase the corresponding independent variable (X) by one unit holding everything else constant. The epsilon (ε) is the error term for the model.

From the different economic impact variables in the data set the best variable to use as a dependent variable for this study would be the total economic damages done (adjusted to current prices), the adjusted costs will make it so that comparisons can be done between the observations and the total economic damage is exactly what we want to be able to determine which type of disaster has the biggest impact.

The choice for the independent variables that will be included is total deaths and total amount of people affected as these two variables have relatively high correlation with the amount of damage that is done with a value of ρ=0,64 and ρ=0,68 respectively, and is highly relevant to the topic. The variable for total amount of people affected includes injured + affected + homeless, including this variable together with the total amount of deaths would capture the total human impact. These variables are also important to determine if the type of disaster even matters or the total amount of damages is somehow mostly dependent on the amount of people that get affected by the disaster.

Other independent variables that will be included in the model to differentiate between the different disasters is of course the natural disaster types. Due to the categorical nature of this data these will be included as dummy variables to capture their respective impact on the total damage. The five different types that will be included in the model is the five most frequent ones in the Philippines: Typhoons, Floods, Earthquakes, Volcanic and Droughts. The estimated coefficients for these variables can then be used to determine which type of disaster event has a bigger impact on the total cost. One problem that arises with the use of dummy variables is the dummy variable trap. The solution to this is to either drop one of the dummy variables and then use one of the types as a baseline and interpret the intercept as this disaster type and the other dummy variables as the difference from this baseline. Another solution is to just use all the dummy variables but drop the intercept altogether (Stock & Watson, 2019) The choice for my model will be to use the disaster type that is the most frequent (Typhoons) as a baseline by dropping this one from the regression and thus the coefficients for the other types can be seen as the difference in costs compared to typhoons. The reason for doing it this way instead of dropping the intercept is because I want to test if there is a difference between the different disaster types and not just if there is a difference from zero as would be the case with the dropped intercept.

The econometrics software that will be used to compute and analyze the regressions will be Gretl. To make the 450 total observations in the database actually useable in the regressions I had to do some cleaning of the data, the criteria used were:

I. There has to be a value for the total cost
II. Removal of observations with errors in death/affected
III. At least one death

The first one is quite self explanatory since I use the total cost as the dependent variable, if the observation in the data does not have a value for it then it can not be used in my regression. The second criteria of removing observations that had errors in the estimated deaths and affected was due to the fact that after looking at the data there seemed to be some form of measurement or estimation error for a very small amount of observations in the early period during 1900. One observation had a value of almost a thousand deaths but less than ten people total affected. This does not really make any sense so the removal of similar observations were done. The third criteria of only including the observations with at least one death was due to the fact that it was not established if the missing values for the total death column were due to the fact that there was no estimation done, like for the total cost of some events or that it was due to there actually being zero deaths during the event.

After cleaning up the data so that it become useable the variable for droughts had to be dropped since there was no longer any observations with a drought event left. This leads to the inclusion of four dummy variables now instead of five. The total amount of observations decreased from 450 to 329.

With this is mind the first iteration of the regression model will look like:

$$TotalDamage = \beta_0 + \beta_1 TotalDeaths + \beta_2 TotalAffected + \beta_3 Earthquake + \beta_4 Volcanic + \beta_5 Floods + \varepsilon$$

A detailed explanation of the terms in the model is provided below:

Terms	**Explanation**
TotalDamage	The total costs of the event taken from the EM-DAT database, adjusted to 2022 prices.
β_0	This is the baseline that the other dummy variables will be tested against. When all other dummy variables = 0, this value will show the impact a typhoon has on the costs.
β_{1-2}	The constant coefficients for the independent variables of total affected and total deaths. Can be seen as how much the expected value of TotalDamage will increase as we increase one of these variables by one unit holding everything else the same.

Terms	Explanation
β_{3-5}	These coefficients show the difference in impact on total damage by comparing the various dummy variables to the baseline. A negative value indicates that this specific dummy variable has less impact on cost relative to the baseline β_0.
TotalAffected	This variable is the column of Total Affected in the EM-DAT database that sums the affected+injured+homeless.
TotalDeaths	This variable is the column of Total Deaths in the EM-DAT database that includes deaths + missing.
Earthquake	Binary dummy variable that assumes the value of 1 if the event was an earthquake or 0 otherwise.
Volcanic	Binary dummy variable that assumes the value of 1 if the event was a volcanic activity or 0 otherwise.
Floods	Binary dummy variable that assumes the value of 1 if the event was a flooding or 0 otherwise.

Table 1. *Explanation of the terms included in the regression model.*

To make sure that the regression is good and I get unbiased estimators for the coefficients in my regressions some assumptions needs to be made (Stock & Watson, 2019) such as linearity, no multicollinearity, constant variance in the residuals and tests for these assumptions will be done. The tests for these assumptions will be made in Gretl. First of all a test was made to check wether misspecification was present, this was done using a Ramsay RESET test using both squares and cubes. The null hypothesis for this test is that the specification is adequate and for my model the p-value for this test was incredibly low so there is evidence of misspecification. To check the no multicollinearity a VIF test was conducted, a value of above 10 would indicate a problem. All of the variables had a value below 1.3 so a conclusion can be made that there is no multicollinearity present. White's test was used to test the presence of heteroskedasticity, the null hypothesis here is that heteroskedasticity is not present. This also gave a very small p-value so the null was rejected and it can be concluded that heteroskedasticity is present. As indicated by Stock and Watson (2019), the solution to this problem would be to use heteroskedasticity-robust standard errors that would then lead to inference results being valid with a large amount of observations as we have here.

Due to the numerous problems in the first model a second model was constructed to see if there could be improvements. The second improved iteration of the regression model:

$$ln(TotalDamage) = \beta_o + \beta_1 ln(TotalDeaths) + \beta_2 ln(TotalAffected) + \beta_3 Earthquake + \beta_4 Volcanic + \beta_5 Floods + \varepsilon$$

The second model uses the same variables as the first one but with a log transformation of the TotalDamage, TotalAffected and TotalDeaths variables using the natural logarithm (ln). The first reason for this was that both the data for the total damage and total affected had such a big difference in the magnitude of the values so that some form of transformation to scale it down better seemed like a great choice. The second reason is for the interpretation of the results, the interpretation of a one unit increase in the amount of deaths or affected leading to x amount of increase in total cost is not really that intuitive unless you also understand what level of magnitude the average cost would be. The log-log model gives a more interesting interpretation of the coefficients which I will return to in the next chapter.

The tests that were conducted on the first model was once again used to test this model. Test for misspecification was done with Ramsay's RESET where the null hypothesis is that the specification is adequate. This gave a p-value of 0,8 indicating that there is not enough evidence to reject the null and the model can be seen as correctly specified. This is an improvement to the previous model where misspecification issues were present. To check for multicollinearity VIF was once again used and the value for each variable were all way below the threshold that indicates a multicollinearity problem so there are no such problems in this model. Lastly White's test to check the presence of heteroskedasticity was conducted, the p-value was very low so the null was rejected and heteroskedasticity is determined to still be present. Due to this, heteroskedasticity-robust standard errors will be used with the model. All the test results will be included in the appendix.

5. Results and discussion

The first part of this chapter is reserved to the presentation of the results from the previous chapter, the results will then be discussed in the second part of the chapter.

5.1 Regression results

Variable	Coefficient	Std. error	t-ratio	p-value
constant	4.28731	0.561199	7.640	$2.5e^{-13}$ (***)
ln_TotalDeaths	0.582134	0.0657297	8.856	$5.60e^{-17}$ (***)
ln_TotalAffected	0.309005	0.0493787	6.258	$1.24e^{-09}$ (***)
Earthquake	0.272357	0.311455	0.8745	0.3825
Volcanic	0.503667	1.03116	0.4884	0.6256
Floods	-1.05343	0.271690	-3.877	0.0001 (***)

P-value(F) of overall regression: $1.39e^{-47}$ (***). Adjusted R-square: 0.479483

Significance levels: p < 0.1 = * , p < 0.05 = ** , p < 0.01 = ***

Table 2. *Results from the second regression model in Gretl.*

The first thing to note from the regression results is that the overall regression is significant at a 1% level with a p-value of $1.39e^{-47}$, the adjusted R^2 shows a value of 0.479483 telling us that about 47.95% of the variation in the dependent variable ln_TotalDamage is explained by the independent variables. Looking at the intercept const (β_0), that was established as the baseline Typhoon we can see that this estimated coefficient has a positive value of 4.28731 and that it is significant at the 1% level.

Looking at the ln_TotalDeaths estimated coefficient (β_1) it has a positive value of 0.582134 and is significant at the 1% level. To interpret this we need to remember that both the dependent variable TotalDamage and the independent variable TotalDeaths was transformed with the natural logarithm, this means that the interpretation no longer is in unit increases but instead it is interpreted as approximate percent changes. In this case a 1% increase in the total deaths will lead to an approximate 0.5821% increase in the total costs.

For the ln_TotalAffected variable the estimated coefficient (β_2) is a positive 0.309005 and significant at a 1% level. the interpretation is the same as the former variable. A 1% increase in the total affected will lead to approximately a 0.3090% increase in the total cost.

For the dummy variables Earthquake and Volcanic the coefficients (β_3 & β_4) are positive but not statistically significant. This means that the evidence was not sufficient enough to show that these disaster types had any significant difference on the impact of total cost compared to the baseline typhoon (intercept). The Floods variable has a negative estimated coefficient of -1.05343, it is also significant at a level of 1%. The interpretation of this is not that the disaster type being floods lead to an expected decrease in the total cost but rather that it has a lower (still positive) impact on total cost when compared to the baseline of typhoons. The exact interpretation of the coefficient is given by Halvorsen and Palmquist (1980) where they show that it is 100*(exp(-1.05343)-1) leading to a decrease in total cost of about -65% when the event type is floods compared to the baseline typhoon and the total affected and total deaths is the same.

5.2 Discussion

From the regression results we can see that the significant variables were: typhoon (intercept), total amount of people affected, total amount of deaths and floods. The positive relationship that was established between the two independent variables total death and total affected with total damages would be expected. As more people get affected by the event there is a higher probability for economic damage to occur. An example would be to consider the same type of disaster impacting an area in the Philippines with a population of five and another area with a population of a thousand, just the sheer amount of more things that can be damaged or destroyed in the second area will most of the time lead to higher economic costs.

The main thing to note is that there was no significant difference established between the natural disaster types typhoon, earthquakes and volcanic activity. One issue that was also noted that could have led to the results of earthquake and volcanic activity was that the number of observations of these events in the data was quite small with only about 7% of the total. The only significant difference that was shown in the model was between typhoon and floods. The negative value for floods implies that when the disaster type is a flooding and we hold the total affected and total deaths fixed the impact on total cost will be less than it would be if it was the same scenario but with a typhoon event. An explanation for this could be that it is easier to prepare for and handle a flooding event compared to a typhoon.

An abnormal level of rainfall or intensity is usually what causes the majority of floods, they are not really instantaneous and take some time to form. This together with the fact that the water in the floods will need to actually flow to the areas that are inhibited to cause big economic costs. The costs can be mitigated by buildings being built higher from the ground so that the water level of the floods will need to be higher to cause any damage to the building. Other measures to handle the flooding could be in the form of flood walls, construction of various channels to lead water away, more effective drainage systems. Typhoons on the other hand are accompanied by storms that cause massive wind storms, wind does not need to move on top of areas or flow to areas. There are not really that effective methods to deal with this since the destructive power of the wind storms are usually way stronger than the power of the water during flooding events. This would lead to typhoons impacting the total costs on a higher level compared to floods.

The result indicating that there was no difference in total cost between the three other disaster types is very interesting. A reasonable assumption could be that the disaster types that are more unpredictable and random such as earthquakes and volcanic eruptions would have the highest impact on the total cost since the people would not be as well prepared. Typhoons form above the northwest pacific ocean and the paths and landfall can usually be predicted and people can prepare in advance. The fact that the study could not prove a difference between the three on the impact on total cost leads to some very cool insights. Even though typhoons are seen and warnings can be made before landfall so people can prepare they still have the same effect on the total economic cost afterwards as the more sudden unpredictable events such as earthquakes and volcanic activity.

Looking back at the inverse u-shape relationship that was found by Schumaker and Strobl (2011), for countries with high exposure such as the Philippines they use the total combined costs of the natural disasters and not the individual disaster types when they established this relationship. It might be that the different types of disasters have have their turning point at different levels of GDP per capita which could lead to us being on different parts of of the curve depending on disaster type. One explanation for the negative difference between floods and typhoons could be that for typhoons we are on the upwards sloping part of the u-shape curve and for floods we are on the downward sloping part before the turning point.

An explanation as to why there could be no difference established in costs between typhoons and the two more unpredictable ones can be given by the study by Jha et al. (2018) where they showed that people affected by typhoons are more likely to fall into poverty which would mean that more people would have their resilience and ability to mitigate the impacts of future events hampered. The poverty situation would likely mean that more people won't have resources to move away to a less disaster prone area and will be continuously hit by future typhoons, they also won't have the funds to invest in damage mitigation efforts such as better quality buildings or other items with the purpose of decreasing damages. This additional secondary effect of poverty can offer an insight as to why the impact on costs by typhoons is bigger than floods and why we can't establish a significant difference between the impact on costs by the more unpredictable types and typhoons.

Due to the fact that the study couldn't establish that one specific type of disaster would lead to the highest costs it becomes more difficult to discuss potential improvements that could be done to limit the costs of the disaster so a more general review seems appropriate. Looking back at the Disaster Risk Index we can see which general areas contribute to the Philippines being ranked as number one, the two things that increases the risk a lot for the Philippines is the high values in lack of coping abilities and lack of adaptive capacities. The coping abilities refer to how well the country can handle the natural disaster in the immediate aftermath such as mitigation of damages and relief efforts. Adaptive capacities is a measure of the long term capacity of the country to change and adapt to reduce the impact of natural disaster events in the future before they happen, in the index this is determined by expenditure on research, education and investments in disaster prevention and mitigation.

Being able to handle the situation in the immediate aftermath is of course an impart thing so that the people that are affected get the help that they need and to limit not only the economic cost but also the amount of people that die. The disaster fund that is provided by the local governments in the country is one of the main tools for the coping ability but maybe it is time to rethink how it is used, if there is money over from the last year then using this to increase the adaptive capacities would be a good idea. Another great improvement could be by adding another budget requirement law for the local governments to be able to create a fund that can be used to increase the long term adaptive capacities.

Since the country has such high exposure with natural disaster events occurring multiple times each year and showing no signs of stopping in the future it might be a good choice to just invest more into increasing the long term adaptive capacities instead of the coping capacity. The disaster events will just keep on happening so improving the short term coping abilities will just make it so that the people will just have to make the disaster events a part of their life for the rest of their lives and expect economic costs. Changing the focus to a more proactive approach such as the long term adaptive capacity rather than the short term reactive approach would be much better since if the adaptive capacity becomes good enough then there will not be a need for a high coping capacity since the long term investments that were made reduces or removes the negative impacts of future events. From one of the previous studies we could also see that foreign direct investments had a positive impact on GDP per capita and the rebuilding and rehabilitation after an event leads to a perfect opportunity and incentive to invest, improve and adapt buildings and infrastructure to improve the economy as a whole while also contributing to decreasing the future costs of disaster events.

6. Conclusion

The goal of the study was to see if the natural disaster type had an impact on the total cost in the aftermath of an event, to be able to determine this a regression model using the total economic cost as the dependent variable was created and data for the various natural disasters were taken from the EM-DAT database. The model included the total amount of people affected and amount of deaths together with the most frequent disaster types in the Philippines: typhoons, floods, earthquakes and volcanic activity.

The study could not find a significant difference on the impact of total cost for the disaster types: typhoon, earthquake and volcanic activity however a significant negative difference on the impact on total cost could be established between floods and typhoons, with the same amount of people affected and the same amount of deaths an event being a flooding would lead to a lower total economic cost compared to if it was a typhoon. The study concluded with a discussion about improvements that could be made to limit the economic costs in the future. Since it could not be determined which of the disaster types would lead to the higher costs a general review of improvements was done using the Disaster Risk Index as a central discussion point. Due to the high exposure risk and the country being hit by multiple natural disasters every year a focus on improving the adaptive capacities over the coping capacities was suggested.

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Appendix

Appendix 1. Full results from the second regression model

```
Model 2: OLS, using observations 1-329
Dependent variable: ln_TotalDamagesAdjusted
Heteroskedasticity-robust standard errors, variant HC1

                     coefficient   std. error   t-ratio   p-value
  ---------------------------------------------------------------
  const               4.28731      0.561199      7.640    2.50e-13 ***
  ln_TotalDeaths      0.582134     0.0657297     8.856    5.60e-17 ***
  ln_TotalAffected    0.309005     0.0493787     6.258    1.24e-09 ***
  Earthquake          0.272357     0.311455      0.8745   0.3825
  Volcanic            0.503667     1.03116       0.4884   0.6256
  Floods             -1.05343      0.271690     -3.877    0.0001   ***

Mean dependent var   9.677135   S.D. dependent var   2.324118
Sum squared resid    908.1419   S.E. of regression   1.676778
R-squared            0.487418   Adjusted R-squared   0.479483
F(5, 323)            66.44989   P-value(F)           1.39e-47
Log-likelihood      -633.8547   Akaike criterion     1279.709
Schwarz criterion    1302.486   Hannan-Quinn         1288.796
```

Appendix 2. Ramsay's RESET test on model 2

```
Auxiliary regression for RESET specification test
OLS, using observations 1-329
Dependent variable: ln_TotalDamagesAdjusted

                     coefficient    std. error   t-ratio    p-value
  -----------------------------------------------------------------
  const               4.28884       4.00182       1.072     0.2847
  ln_TotalDeaths      0.277517      2.03864       0.1361    0.8918
  ln_TotalAffected    0.160311      1.08406       0.1479    0.8825
  Earthquake          0.109753      1.00777       0.1089    0.9133
  Volcanic            0.230949      1.92001       0.1203    0.9043
  Floods             -0.554836      3.69259      -0.1503    0.8807
  yhat^2              0.0324080     0.359228      0.09022   0.9282
  yhat^3             -0.000448492   0.0120673    -0.03717   0.9704

Test statistic: F = 0.221089,
with p-value = P(F(2,321) > 0.221089) = 0.802
```

```
RESET test for specification -
  Null hypothesis: specification is adequate
  Test statistic: F(2, 321) = 0.221089
  with p-value = P(F(2, 321) > 0.221089) = 0.801767
```

Appendix 3. Multicollinearity test using VIF on model 2

```
Variance Inflation Factors
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

   ln_TotalDeaths    1.412
 ln_TotalAffected    1.408
       Earthquake    1.045
         Volcanic    1.006
           Floods    1.053
```

Appendix 4. White's test for heteroscedasticity on model 2

```
White's test for heteroskedasticity
OLS, using observations 1-329
Dependent variable: uhat^2

                      coefficient  std. error  t-ratio   p-value
  ---------------------------------------------------------------
  const               12.3906       5.33617     2.322    0.0209   **
  ln_TotalDeaths      -2.18235      1.01048    -2.160    0.0316   **
  ln_TotalAffected    -0.562425     1.01672    -0.5532   0.5805
  Earthquake          -9.78208      4.87961    -2.005    0.0459   **
  Volcanic             3.05735     22.1057      0.1383   0.8901
  Floods              -2.26969      3.52496    -0.6439   0.5201
  sq_ln_TotalDeaths    0.0804522    0.0917030   0.8773   0.3810
  X2_X3                0.0688707    0.0991068   0.6949   0.4876
  X2_X4                0.645655     0.566324    1.140    0.2551
  X2_X5                0.419110     0.911653    0.4597   0.6460
  X2_X6                1.70465      0.588954    2.894    0.0041   ***
  sq_ln_TotalAffec~    0.00257377   0.0513234   0.05015  0.9600
  X3_X4                0.518303     0.506387    1.024    0.3068
  X3_X5               -0.168803     1.79685    -0.09394  0.9252
  X3_X6               -0.200884     0.341229   -0.5887   0.5565

  Unadjusted R-squared = 0.107640

Test statistic: TR^2 = 35.413466,
with p-value = P(Chi-square(14) > 35.413466) = 0.001276

White's test for heteroskedasticity -
  Null hypothesis: heteroskedasticity not present
  Test statistic: LM = 35.4135
  with p-value = P(Chi-square(14) > 35.4135) = 0.00127641
```