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The Effects of Natural Disasters on Long Run Growth

Aaron Popp

ABSTRACT. This paper seeks to determine the relationship between natural disasters and long run growth. Natural disasters affect several important macroeconomic variables, most notably technology, that can increase or decrease economic growth. Recovery following disasters is important, and the institutions of a country help determine how the recovery progresses. Institutions also help determine the outcomes of some events, such as inflation, that could affect long run growth. Countries can help maximize the positive effects of natural disasters on growth by improving their response to disasters and preparing for the next disaster.

I. Introduction

There were earthquakes and floods of extraordinary violence, and in a single dreadful day and night all your fighting men were swallowed up by the earth, and the island of Atlantis was similarly swallowed up by the sea and vanished. [Plato, 1977, 38]

Tales told through the generations of the destruction of Atlantis and Pompeii by natural disasters show that natural disasters fascinated and affected listeners throughout history. Natural disasters still play a vital role in modern life, costing countries billions of dollars in damage and killing thousands annually. Most previous research on natural disasters focused on their short run effects on economies. Only one study has focused exclusively on the long run effects of natural disasters on growth, so the nature of the relationship between natural disasters and long run growth is still an open question. This paper seeks to determine the relationship between natural disasters and long run growth. The relationship is complicated. Natural disasters affect key macroeconomic variables, notably technology, that affect long run growth. The effects of natural disasters on the macroeconomic variables can be positive or negative depending on the country's institutions and how the country recovers following disasters. The type of disaster that affects a country matters as well; droughts and geologic disasters tend to have a more negative effect on growth than climatic disasters. Countries cannot

directly control most of the macroeconomic variables and effects following a disaster, but any effort to improve their institutions, recovery following disasters, and preparation for disasters pays off in the long run. Depending on the circumstances, natural disasters can foster long run growth.

A. CATEGORIES OF NATURAL DISASTERS

There are two broad categories of natural disasters. Climatic disasters result from atmospheric phenomena. Floods, hurricanes, and droughts are the major climatic disasters that affect countries on a large scale. Floods occur when torrential rainfall or snowmelt causes rivers to overflow their banks and inundate surrounding areas [Abbott, 2004, 362-363]. Hurricanes are large storms that form in the tropical and subtropical regions of the world where the water is warm. They need a constant supply of warm water in order to stay intense; any interaction with land or colder water weakens hurricanes. The effects of hurricanes are the strongest near coastlines, on islands, and in mountainous regions, but the effects on each of those regions are different. Near coastlines and on islands, the winds and associated storm surge, which is the sea level rise associated with the passage of hurricanes, cause the most damage. In mountainous regions, the increase in elevation helps to produce areas of enhanced rainfall that can cause significant flooding [Abbott, 2004, 304-306]. Droughts are periods of below-average rainfall that affect agriculture and the water supply to the regions affected by the drought [Abbott, 2004, 265-266]. Climatic disasters affect people and capital through forces of wind and water.

Geologic disasters include earthquakes, volcanoes, and the disasters that occur as a result of geologic changes. Earthquakes are the most significant geologic disaster. The direct effects of an earthquake, however, depend on the economy of the region. Earthquakes that strike rural areas tend to cause less physical damage, because agricultural interests are not as affected as much as industrial interests. They do not kill large numbers of crops and livestock, but collapsed buildings are common in areas struck by earthquakes. Volcanoes erupt and send lava, mudflows, ash, and debris into the surrounding area. Geologic disasters cause other, secondary disasters. Earthquakes can trigger landslides, tsunamis, and damaging aftershocks, and volcanoes can cause tsunamis as well [Abbott, 2004, 112 and 161]. The effects of geologic disasters are

less predictable than the effects of climatic disasters because of the variety of secondary disasters that they cause.

B. THE EVIDENCE OF A LINK BETWEEN NATURAL DISASTERS AND LONG RUN GROWTH THUS FAR

Economists have not come to a consensus regarding the effect of natural disasters on long run growth. Only one study concluded that natural disasters can spur long run growth. Skidmore and Toya [2002, 682] concluded that climatic disasters, excluding droughts, lead to increased growth rates, but they found some evidence that geologic disasters cause a decrease in economic growth. They attributed the increase in growth rates after climatic disasters to an increase in human capital accumulation and an increase in technology, and they attributed the decrease in growth rates after geologic disasters to a decrease in physical capital and the loss of human capital from the initial loss of life [Skidmore and Toya, 2002, 671-672]. While Skidmore and Toya are the only authors who support the idea that natural disasters can spur long run growth, their study provides substantial evidence for the claim.

Other studies conclude that natural disasters either hurt or do not harm long run growth. Rasmussen [2004, 11-12] concluded that the long-term effects of natural disasters on growth are ambiguous. He noted that natural disasters could decrease long run growth by irrevocably destroying agricultural, fishing, or other natural resources. Rasmussen also noted that reconstruction efforts could crowd out productive investments, increase the rate of interest and reduce investment, and lead to inflation or financial crises, all of which would decrease economic growth. A regression on natural disaster occurrence controlling for land area and the population affected found a positive relationship with GDP growth. Rasmussen explained that the relationships were marginally significant and “could be driven by other factors.” [Rasmussen, 2004, 11]. Auffret [2003, 17] found that the effect of natural disasters on long run growth was difficult to predict, because the growth prospects of the country depended on how reconstruction efforts progressed. Replacement of physical capital was vital. If the economy did not replace the physical capital, then a negative effect on growth would result. He did not provide any empirical evidence to support his claims. Benson and Clay [2003, 14-19] emphasized that the economic impacts of natural disasters depend on a myriad of factors but saw few reasons why natural disasters would cause long run growth. They emphasized that each natural disaster has

unique effects. While the majority of the studies support the idea that natural disasters hurt or do not harm long run growth, the studies do not support the claim with substantial evidence.

II. The Effect of Natural Disasters on Key Macroeconomic Variables

Natural disasters affect certain macroeconomic variables that, in turn, help determine long run growth. Natural resources, physical capital accumulation, human capital accumulation, and technology are the four key macroeconomic variables studied. All four macroeconomic variables usually have a positive effect on long run growth. If the net effect of natural disasters on the macroeconomic variables is positive, then natural disasters aid long run growth. If the net effects on the macroeconomic variables are negative, then natural disasters hurt long run growth. In most cases, the net effect is ambiguous, but some characteristics of countries and empirical research by Skidmore and Toya help clarify some of the effects of natural disasters on macroeconomic variables and thus long run growth.

A. AN INTRODUCTORY NOTE ABOUT INSTITUTIONS

Institutions are the norms, rules, and mechanisms that help society operate. Countries with sound institutions do not have significant social, legal, or governmental barriers to growth. There are neither significant barriers nor steep costs to open businesses, and, in general, the government allows markets to operate freely. A country with sound institutions is not a corrupt country; leaders do not require bribes or kickbacks to enforce laws and to allow entrepreneurship. Studies have shown that countries with lower measures of corruption, a sign of institutions more conducive to growth, tend to grow at a relatively faster pace [Aron, 2000, 116-120]. Since institutions and the economy are closely intertwined, the relationship between the two is symbiotic. Better institutions allow for growth, and growth allows for better institutions.

B. THE IMPACT OF NATURAL DISASTERS ON NATURAL RESOURCES

Natural disasters affect a country's natural resource stock. Hurricanes

and other storms can topple vast stretches of forest. Hurricane Isabel in 2003 caused over \$550 million in damage to timber in North Carolina [Trickel, 2003, 3]. Hurricanes and droughts could wash or blow away topsoil and decrease soil fertility, which would hurt agricultural yields. Additional fertilizer could compensate for the depleted soil. The destruction of crops and death of livestock in a disaster would also decrease agricultural yields in the short run. Tourism dependent on natural wonders could suffer. The extratropical remnants of Tropical Storm Delta toppled Tenerife's most important tourist attraction, a rock structure known as "El Dedo de Dios" [*The Tenerife News*, 2005, para. 6]. Excluding the effects of disasters on natural wonders, natural disasters have short run negative effects on the natural resource stock.

The impact of natural disasters on natural resources is not exclusively negative. Floods, for example, provide sediments to the surrounding flood plain that increase agricultural yields [Abbott, 2004, 351]. Volcanic eruptions deposit ash, which enriches the soil [Abbott, 2004, 170]. Farmers would not benefit from the disasters immediately, and farmers would not reap the benefits in a lump sum either. Tourism can see a boost from some disasters as well. Relatively docile volcanoes in Hawaii attract tourists, and other tourist attractions exist because of ancient disasters. Crater Lake in Oregon exists inside the caldera of Mount Mazama, a volcano [Abbott, 2004, 172-173]. A disaster that does not significantly damage natural resources but provides a lasting benefit may boost the natural resource stock of a country. The positive effects of natural disasters on natural resources tend to affect countries in the long run. People can see the immediate damage from natural disasters on agriculture, but they cannot immediately see the benefits from natural disasters. The net effects of natural disasters on the natural resource stock depend on the country and the situation, but the effect is not exclusively negative.

C. THE IMPACT OF NATURAL DISASTERS ON PHYSICAL CAPITAL ACCUMULATION

Physical capital accumulation plays a vital role in achieving economic growth. Physical capital allows workers to produce more than what they could without tools. Since economic growth is directly related to the output of each worker, a greater amount of physical capital in an economy should yield a higher level of per capita income. The influence of

physical capital accumulation on economic growth depends on if there are enough qualified workers to use the physical capital. Simply building more physical capital without a sufficient labor force to work the capital will not result in economic growth. While the exact empirical avenues through which physical capital accumulation increases economic growth are the subjects of controversy, the general consensus among economists is that countries with more physical capital tend to be more prosperous [Temple, 1999, 137-138].

Natural disasters destroy physical capital. The change in the physical capital stock depends on the amount of investment that occurs after the disaster. Countries, if they can, seek to repair and rebuild the physical capital. In countries where institutions are not healthy, the reconstruction can be more complicated. Bureaucratic barriers, corruption, and low rates of insurance can delay or even prevent reconstruction of physical capital. Corrupt leaders could hoard foreign aid or divert the aid to fund pet projects rather than the projects that would aid the country the most. As long as countries replace the physical capital, disasters should not affect physical capital accumulation, but poor institutions could cause a decrease in physical capital accumulation.

Empirical evidence indicates that natural disasters will have a negative effect on physical capital accumulation if any relationship exists. Skidmore and Toya [2002, 676 and 678] show that any relationship between natural disasters and physical capital accumulation is negative, but the relationship is not consistently statistically significant across multiple tests. The weak relationship exists because of human capital accumulation. Human capital accumulation may increase following a natural disaster, which could increase the return to physical capital. The increased return to physical capital leads to increased physical capital accumulation.

D. NATURAL DISASTERS AND HUMAN CAPITAL ACCUMULATION

Human capital accumulation positively affects economic growth in most circumstances. If the technology embodied in the physical capital of an economy is sophisticated, then investment in human capital will yield higher productivity. Investment in human capital yields more educated, competent workers, and workers who can learn and apply new concepts quickly are more productive than workers who cannot. Investment in

human capital, however, is not a sufficient condition for economic growth. A country with insufficient opportunities for workers may not have the physical capital or types of jobs necessary to justify the investment in human capital. Years of collegiate education are unnecessary if people simply toil in the fields afterwards. Examples of countries in which investment in human capital has not yielded a boost in economic growth exist, but the general consensus among economists is that human capital accumulation positively influences economic growth [Temple, 1999, 139-140].

Natural disasters affect human capital accumulation in several ways, which makes the analysis difficult. Initially, natural disasters substantially reduce human capital only if there is a substantial loss of life. Between 1970 and 2001 (excluding droughts), only three natural disasters resulted in the deaths of over 100,000 people and only nineteen natural disasters resulted in the deaths of over 10,000 people. Of the natural disasters that resulted in the deaths of over 10,000 people, five occurred in India, three occurred in Bangladesh, and two occurred in Iran. The remaining disasters occurred in Central and South America, Armenia, and Turkey [Abbott, 2004, 5]. While the loss of life was tragic, no country during the period suffered a disaster that resulted in the deaths of a substantial percentage of the population. Only epic natural disasters that strike without warning, such as the tsunami in the Indian Ocean in 2004, result in catastrophic loss of life. Improved warning for natural disasters allows people to take precautions to avoid harm. As warning and prediction technologies improve, the number of lives lost in disasters should fall. For most countries and most natural disasters, the effect of natural disasters on the population level is relatively negligible and will decrease with better warning and prediction technologies.

Another potential impact of natural disasters on human capital accumulation results from damage to the educational system. Damage to schools and universities may decrease human capital accumulation, because students forced out of classes lose out on the education that they otherwise would have received. Hurricane George in 1998 destroyed 4% and damaged 28% of the schools in the Dominican Republic, and the government used 443 of the largest schools as shelters for the homeless. The damage forced an estimated 100,000 students out of class for several weeks [Auffret, 2003, 23]. If sufficient funding to rebuild the schools and universities does not exist, then the damage to human capital accumulation would be more severe as time progressed.

Disasters can have negative effects on human capital even if schools remain open. In poor countries, when a family loses a source of

income because of a disaster, some or all of the children may need to leave school to reduce expenses and increase the family's income. Natural disasters that cause a severe initial shock to the economy may lower human capital accumulation in later years, because many young students leave school for an extended period. Several studies have found that economic crises result in lower primary and secondary school attendance rates. Attendance rates for older students, however, may increase following economic crises. If the real wage falls immediately following a disaster, then the opportunity cost for students to attend school falls, and more students will attend school. Older students are more likely to have a job, so the change in the real wage would push them back into school [Skoufias, 2003, 1092].

Substitution away from physical capital accumulation may have a net positive effect on human capital accumulation despite the factors discussed above. Since the risk to physical capital increases because of natural disasters, investment in human capital becomes relatively more attractive. People and governments may increase investment in the education system and job training, which would increase human capital accumulation.

Countries with better institutions are able to avoid the factors that impede human capital accumulation following disasters. Schools will reopen more quickly, because countries will be able to repair the damage more quickly or transfer the students to other areas not damaged by the disasters. Countries with better institutions tend not to allow child labor, so pulling students out of class to work is not feasible. Parents are left with the choice of keeping their children in school or pulling them out to help with the recovery. Schooling provides parents with a sort of child care service, so parents who let their children go to class are able to focus their energies on recovery and prosperity.

The empirical evidence shows that natural disasters can increase human capital accumulation. Skidmore and Toya [2002, 678] found that human capital accumulation increases following climatic disasters, but they did not find a statistically significant relationship between human capital accumulation and geologic disasters.

E. THE IMPACT OF NATURAL DISASTERS ON TECHNOLOGY

Vital to the argument that natural disasters induce long run growth is the effect of natural disasters on the level of technology in a country. A higher level of technology embodied in physical capital makes physical

capital more productive so long as the human capital is sufficient to operate the new technology. Technology also increases the return to human capital. Since capital becomes more productive, worker productivity increases. Economic growth results from the increase in productivity. Since natural disasters destroy physical capital and the infrastructure of an economy, countries have an opportunity to rebuild with new applied technology following the disaster.

Measuring the level of technology in use in an economy, however, is a problematic endeavor. Skidmore and Tova [2002, 678-680] analyzed the relationship between natural disasters and total factor productivity. Total factor productivity directly measures the productivity of labor and capital and thus indirectly measures the level of technology embodied in capital. It also indirectly measures human capital productivity, institutional stability, natural resources, and the political climate. They found that total factor productivity increases following climatic disasters. Following geologic disasters, they found no statistically significant relationship. Natural disasters increase, or at least do not decrease, the level of technology in a country.

There are several possible objections to their supporting evidence and the argument that the amount of technology embodied in capital increases following a disaster. First, as already noted, total factor productivity does not measure the level of technology embodied in capital; it also implicitly measures human capital productivity, institutional stability, natural resources, and the political climate. The other possible effects of natural disasters on the indirectly measured variables taint the measurement of technology.

Second, reconstruction does not necessarily occur following a natural disaster. If there are institutional factors that prevent or hamper reconstruction, then physical capital accumulation in an economy will fall because of the disaster. The positive effect from better technology embodied in capital depends on the replacement of the capital lost following a disaster. The boost in productivity from better technology cannot occur if the country does not build the capital to use the technology.

Third, disasters that destroy relatively modern physical capital do not have a significant impact on long run growth. Unless a breakthrough occurs or costs of significantly better technology plummet in the interim between disasters or the construction of the capital, the marginal benefit of the increase in technology is minimal. If the increase in technology

from a disaster is small, then the cost to replace the capital may outweigh any potential gains from the increased productivity from the technology. Fourth, while technology in a country may increase, institutional factors may negate any technological improvements in a country. Industries that have strong ties to the government could influence the government to ban or discourage the spread of technology that hurts those industries. After World War II, the steel industry in the United States suffered. Other countries, such as Japan and Korea, greatly expanded their share of the international steel market. Producers of steel in the United States, with the support of the United States government, sought anti-dumping cases against foreign producers of steel [Howell et al, 1988, 37 and 514-517]. While the steel example is not an example of natural disasters and their effects, it is conceivable that governments would take similar protective actions after disasters to prevent new technologies from spreading if the technologies harmed favored domestic industries in a similar manner.

Fifth, recovery efforts could divert resources away from research and development. Technology does not simply appear. Firms or governments must invest in research and development to achieve technological breakthroughs. Disasters strain resources, so investment in research and development could decrease and technological growth would suffer.

The objections raised affect countries in different situations in different ways. All countries are vulnerable to the problem of disasters destroying relatively modern capital and, depending on who is in power, the problem of governments protecting domestic industries from new technology. Relatively prosperous countries with healthier institutions should not see any impacts from political instability or forces that hamper recovery after a disaster. The countries could divert money away from research and development, because more prosperous countries tend to have more investment in research and development. Less developed countries with poorer institutions would need to worry about recovery efforts, human capital accumulation, and political instability the most. Since less developed countries tend to have lower budgets for research and development (and initial levels of technology), disasters do not necessarily have an impact on technological innovation in developing countries. The objections raised may, in some cases, be sufficient to reverse the anticipated increase in technological application following a natural disaster. The empirical evidence indicates that the effects of the various objections do not completely negate the positive boost to

technology. Countries that recover sufficiently and avoid the other pitfalls should still see a boost in technology following natural disasters.

F. DROUGHTS: A DIFFERENT SORT OF DISASTER

Droughts do not affect the macroeconomic variables as other disasters affect them. Droughts do not usually destroy physical capital, so the increase in technology embodied in capital that can result from other disasters will not occur because of a drought.

In developed countries with sound institutions, droughts do not endanger lives. They affect mainly agricultural interests and the only effect that the average person may see is a restriction on water usage. Agricultural interests in countries with good institutions will be able to survive the initial impacts of droughts. Insurance protects farmers against the initial economic losses and allows them to continue farming after the disaster. Even if animals die from excessive heat and crops wither, seed can be readily obtained and markets for livestock can readily replace lost animals. The effects of droughts increase as the quality of the institutions falls.

In less developed countries, the effect on agriculture can be more catastrophic. Seed may be shipped in from other countries, but the possible effect on livestock is more catastrophic. It is difficult and expensive in poor countries to ship in replacement livestock. If a drought kills a large percentage of the livestock in any given region, then it will take many years to replace the livestock lost. Until the herds of livestock are replenished, the supply of food falls. Skidmore and Toya [2002, 666-667] estimate that it could take 25 years for countries to recover from a drought if a country recovers substantially at all. Growth in countries with an economy based on agriculture, especially on livestock, suffers because of droughts. Taking into account crop failures, droughts can lead to food shortages.

The catastrophic loss of life from droughts results from institutional factors and food shortages. The scarcity of food causes fundamental changes in the economy that reduce growth. Feeding stations constructed during a famine in Ethiopia in the mid 1980's became havens for starving families who did not want to stray far from their lifeline. A lack of infrastructure and governmental organization resulted in locating feeding station far from areas of need [Keller, 1992, 617]. Many families depended on food aid, rather than working their land, to

survive. The displaced people contributed little to the economy, and any businesses or trade to which the displaced people contributed suffered. Schooling for the children of the displaced victims may not occur, so human capital accumulation suffers as well. The economy suffers, and people who suffer and become displaced affect the stability of the country.

Droughts can affect the institutional stability and the political climate of the country, especially if the country is inherently unstable or if the disaster is particularly severe. In Ethiopia, a severe drought in the 1970's and the associated famine over the next decade helped topple Haile Selassie, the leader at the time. Political chaos and civil war followed for the next two decades, and droughts exacerbated the conflict to such an extent that the armed forces began to deny their opposition food as a key strategy [Keller, 1992, 609 and 620-623]. The impact of war dashed any possible boost in growth through an increase in total factor productivity. Certainly, there is sufficient evidence to prove that wars and internal conflicts decrease economic growth [Butkiewicz and Yanikkaya 642-643; Levine and Renault 958; Barro 432, 437]. Growth in Ethiopia has been practically nonexistent to date, and Ethiopia is one of the poorest countries in the world. The droughts and famines certainly contributed to Ethiopia's conflicts and its growth problems.

Droughts are a parasite to economically unhealthy nations whereas other natural disasters are a shock. While droughts can have a direct effect on growth through losses of livestock, droughts can cause fundamental negative changes to the economy. However, it is conceivable that recurrent droughts could promote growth in the long run. If international aid efforts succeed in feeding the population and preventing migration, then droughts could serve as an impetus for diversification. On the whole, it is likely that droughts do not affect the long run growth of developed countries and negatively affect the long run growth of developing countries.

G. THE SIZE OF THE COUNTRY MATTERS: MONTSERRAT, MOTHER NATURE'S WHIPPING BOY

Montserrat is a prime example of the extreme effects that a natural disaster can have on a small country. It is a volcanic island in the Caribbean governed by the United Kingdom, and its territory covers about half of the land area covered by Washington DC. About 13,000 people

inhabited the island before 1995, and about 80% of the economy depended on tourism [Auffret, 2003, 21]. It is a prime example of a small island economy dependent on a single industry to survive.

In 1989, Hurricane Hugo struck the island, and in addition to the \$200 million in damages (over five times the annual GDP of the island at the time) and damage to 98% of the housing on the island, the three largest hotels closed for four months and severe damage occurred to the port facilities [Auffret, 2003, 2122]. The island did recover with time, so Hugo did not prove to be a catastrophic blow.

In 1995, the catastrophic blow came. The Soufriere Hills volcano became active, and subsequent eruptions through 1998 rendered much of the island uninhabitable and destroyed Plymouth, the capital [Auffret, 2003, 21-22; Thomas-Hope, 2001, 93]. The eruptions forced 90% of the islands inhabitants off the island, and only about half have returned. Besides the mass exodus of people, the financial system of Montserrat nearly collapsed as well. The Montserrat Building Society, which was the most important bank on the island, nearly collapsed after the disaster. Insurance companies pulled out of the island, and the Montserrat Building Society faced a bank run [Benson and Clay, 2003, 7]. Without international assistance, many refugees from Montserrat would have lost their savings as well as their homes.

Montserrat is particularly vulnerable to natural disasters because of its small size and heavy reliance on tourism. Hurricane Hugo demonstrated Montserrat's vulnerability to natural disasters in the short run, but its long run effects on growth were negated by the volcanic eruptions in the mid 1990's. Much of the island remains uninhabitable because of the eruptions. The Soufriere Hills volcanic eruptions effectively demonstrated Montserrat's vulnerability in the long run.

Thus, tiny countries that depend on a single industry are the most vulnerable to natural disasters. Most natural disasters produced severe local effects and milder effects on a larger scale, so disasters tend not to decimate the economies of large nations. The economies of tiny countries, however, tend to have undiversified economies that leave them vulnerable to large-scale disasters and shocks to the industries on which they depend [Easterly and Kraay, 2000, 2013]. Broad statements about how natural disasters affect long run growth do not consider the extreme case. The volcanic eruption on Montserrat shows how a natural disaster can permanently harm long run growth by rendering the entire country unlivable or undesirable.

Physical capital accumulation, human capital accumulation, and technology are the engines of long run economic growth (or lack thereof) relating to natural disasters. In each case, the theoretical effects of natural disasters on each of the variables are ambiguous on the whole. Understanding how institutions and the recovery process affect the macroeconomic variables is the key to determining how natural disasters harm long run growth. Countries with better institutions will see more positive and fewer negative effects on the macroeconomic variables than countries with poor institutions. Countries with better institutions experience greater long run growth because of natural disasters.

The type of disaster and the size of the country are also important when determining the long run effects of disasters on growth. The empirical evidence hints that geologic disasters and droughts have more negative effects on long run growth than climatic disasters. Geologic disasters may have a more significant effect on the infrastructure of a country, which would hamper recovery efforts and hurt growth. The reasons why droughts are not conducive to economic growth are clearer. Droughts do not positively affect technological progress and have disproportionately negative effects in countries with weaker institutions. A smaller country is simply more vulnerable to natural disasters, even disasters that may have only minor effects in a large country.

III. Other Impacts of Natural Disasters that Could Affect Long Run Growth

The most obvious effects of natural disasters are in the short run, and some effects of disasters in the short run could yield some long run effects. In particular, financial crises caused by disasters could hurt long run growth through inflation. Natural disasters could psychologically harm the people who experience them, which could decrease their productivity. Also, new disaster warning and detection technologies may affect the rates of return to physical capital investment and thus affect physical capital accumulation. The effects in this section are secondary to the effects of the macroeconomic variables, but they are important to some countries.

A. PREDICTING NATURAL DISASTERS WITH NEW TECHNOLOGY

Technology can increase the understanding of natural disasters and reduce the cost of the uncertainty about whether a disaster will occur. The disaster risk of an area is defined as the probability that a natural disaster will damage or destroy physical capital [Skidmore and Toya, 2002, 676]. Disaster risk adds to depreciation. The expected depreciation of capital in a country is depreciation plus the effect of disaster risk on the value of capital. If disaster risk is high, then the expected depreciation of capital will be high as well.

If investors are rational, disaster risk is constant, and information is perfect, then natural disasters will not affect physical capital accumulation. Investors will take into account the increased risk due to disasters and will invest to maximize their returns. Insurance markets will ensure that governments and companies will have the resources to rebuild following disasters. *Ceteris paribus*, an increased disaster risk in an economy decreases the rate of return on investment. If disaster risk is constant, a single disaster should not affect the expected level of depreciation in the long run.

The world is not simple enough to allow such a neat analysis. Disaster risk can change quickly and drastically. Volcanoes can become active without much warning, so disaster risk can change if a new threat develops or an existing threat subsides. Some natural disasters, such as floods, have a nearly constant disaster risk. Other natural disasters can feed off each other and may increase or decrease the risk of another type of disaster. The disaster risk of an earthquake falls after the threat of aftershocks subsides, because the earthquake releases the energy contained within the fault. Even if disaster risk does not change, knowledge about natural disasters changes. Before meteorologists invented weather satellites, limited data about hurricanes prevented meteorologists from forecasting the number and severity of hurricanes in any given year. Recent evidence shows that climate cycles spanning decades affect the tracks, frequency, and strengths of hurricanes [Abbott, 2004, 310]. If meteorologists accurately predict the cycles, then disaster risk would increase before the peak of the cycle and in areas near the predicted tracks of hurricanes. Breakthroughs in the study of other natural disasters will reduce uncertainty when predicting other natural disasters. Recent advances in fault monitoring allow geologists to monitor the tension built up along faults, and they can use the data to predict the threat of an earthquake in any given area [Newshour, 2004, para. 4, 14-20].

As information about natural disaster occurrence increases, investors will benefit from precise measurements of disaster risk. Precise measurements of disaster risk over time will allow investors to adjust for the changing risks posed by natural disasters through insurance. Insurance is the means by which investors can adjust for the risk of a disaster. While insurance is available in many areas affected by disasters, limited data about natural disasters forces insurance underwriters to add an uncertainty premium to policies [Skidmore and Toya, 2002, 677-678]. As data about disasters and the likelihood that they will strike increases because of new technology, the uncertainty premium should fall, and investors should see a greater return to their investments. Physical capital accumulation would increase, and economic growth would increase as well. Hence, forecasting and detection technologies should increase long run growth.

B. A NOTE ABOUT FINANCIAL CRISES CAUSED BY NATURAL DISASTERS

There are two possible sources of inflation in countries that suffer from natural disasters. First, inflation may result from the increased debt burden caused by the recovery. The recovery after a natural disaster produces a cost to society, and governments pay much of the bill. Governments may not be able to afford the additional debt accumulated because of the disaster. Officials may pressure the central bank to print more money to help end a financial crisis, and the result of printing too much money is inflation. In countries with sound institutions, the governments cannot influence the policies of their central banks. Inflation will occur if the government forces the central bank to print off money to pay down the debt, but independent central banks ensure that inflation will not result from the additional debt through direct influence on the central bank. Less developed countries with poor institutions are at the greatest risk of problems associated with financial crises and inflation.

Financial crises certainly can occur following natural disasters. Governments do not necessarily have a budget set aside for recovery from natural disasters or other emergencies. Following a series of earthquakes in Turkey in 1999, the amount of taxes collected from the regions most severely affected fell substantially. A slowdown in the economy in the region was not the only cause for the decrease in tax receipts; the disaster

hampered tax collection efforts as well. The government raised taxes across the board in an effort to compensate for the loss in revenue [Akgiray et al, 2004, 84]. The government had sufficient resources to compensate for the loss in revenue, because it had funding sources from abroad as well. Various international agencies and countries, such as the European Union, the World Bank, and the International Monetary Fund, offered Turkey over \$2 billion in loans. The government spent about \$6.4 billion on recovery efforts; decreases in other areas of the budget of the government allowed the government to spend more on recovery. Economists projected the total cost to the Turkish government, including the initial expense and interest, to be about \$14 billion, which was expected to be a heavy burden on the government [Akgiray et al, 2004, 85-86]. Such an expense caused hardship to the Turkish government, and the same expense could cause inflationary pressures to governments with a higher amount of debt or less international cooperation.

Second, in areas that suffer damage to the infrastructure of the economy, inflation could occur because of market forces. Commodity prices can skyrocket after disasters, because natural disasters disrupt the supply of commodities, such as food, housing, and energy. Demand for commodities also increases, because disasters destroy personal possessions and housing. Controlling commodity prices following disasters is tricky, because people would not want the price controls lifted following the disaster, and it would be difficult to prevent black markets from forming, especially across large regions or rural areas [Skoufias, 2003, 1094]. Thus, the best way to control inflation caused by skyrocketing prices is to restore the infrastructure as soon after the disaster as possible.

Whether the increase in inflation will have a significant effect on long run growth is debatable. The literature on inflation and growth is vast, and there is evidence supporting both views. The conventional view is that the effect of inflation on growth is negative. In addition to the effects of inflation on investment inflation taxes an economy. At a high inflation rate, prices adjust more quickly, so people are not as sure that the cost of goods is reasonable. People also lose faith in the currency, which causes them to revert to inefficient barter to purchase goods. Also, businesses would need to change their prices more often, and changing prices costs money. People would want to hold less cash because of high nominal interest rates, and people would make more frequent trips to the

bank. The costs to an economy caused by inflation imply that inflation hurts growth.

Whether the negative effects of inflation last into the long run is debatable. Bruno and Easterly [1995, 20-21] found that the relationship between long run growth and inflation, even inflation crises, is negligible. Holding out the cases of high inflation, they found no evidence for a decrease in long run growth rates due to the inflation rate. In countries with high inflation and inflation crises, the economies rebounded following a reduction in inflation rates, so there was no damage to long run growth due to inflation. If the conventional wisdom that inflation hurts growth is correct, then financial crises could have an impact on long run growth.

Inflation in poor countries could have short run effects not accounted for in the previous studies that lead to long run consequences to human capital accumulation. First, if wages do not keep up with inflation, then the real household income of a family falls during a period of high inflation. Parents have an incentive to take their children out of school since schooling costs money in many countries. The longer the parents hold their children out, the greater the decrease in human capital accumulation. As discussed previously, older students might experience the opposite effect on human capital accumulation, because the opportunity cost of schooling falls if the real wage falls. The health of children could deteriorate, because parents may not have enough money to provide the proper nutrition to their children. Empirical evidence indicates that inflation causes an increase in malnutrition among children [Skoufias, 2003, 1091-1092]. If malnutrition causes permanent health effects in a sizable number of children, then the possible human capital accumulation for those children falls. Thus, financial crises that cause inflation could hurt long run growth directly or through human capital accumulation.

C. SOCIETAL EFFECTS NOT QUANTITATIVELY MEASURABLE

Natural disasters affect people first and foremost. Even if a disaster does not kill anyone, the emotional and physical effects of the disaster on the population still harm people well after the actual disaster. Some survivors will likely suffer permanent physical disabilities and psychological conditions, such as post-traumatic stress syndrome. Workers who suffer from psychological conditions and disabilities will not be as productive

as they were before the disaster, which could hurt growth if the disaster affects enough people. International aid organizations address the psychological needs of people and families, though their efforts do not necessarily cure mental trauma. One suggestion from the Marmara earthquake in Turkey to help avert the psychological effects of disasters was to emphasize preparation for natural disasters on the community level [Akgiray et al, 2004, 90-92]. Communities prepared for disasters are able to recover more quickly from the initial effects, and people will not feel as helpless following the disaster, which may help avert some of the psychological trauma.

Some short run responses to natural disasters affect long run growth. Technology built to detect and warn against disasters decreases the uncertainty associated with insurance and the returns to investment. As information about disasters improves, the effect on long run growth should be positive. In countries with poor institutions, inflation resulting from financial crises or poor infrastructure could harm long run growth. The effects of disasters on the mental state of the population are important. A demoralized and traumatized population is less productive than a population who successfully endured a disaster. The short run responses to disasters, excluding the direct effect of inflation on long run growth, have indirect effects on the macroeconomic variables that determine long run growth. They are secondary to the more direct effects of disasters on the macroeconomic variables.

IV. Conclusion

Natural disasters certainly have effects on long run growth. The key macroeconomic variables that natural disasters affect are technology, human capital accumulation, physical capital accumulation, and the natural resource stock. All four macroeconomic variables help increase long run growth. Whether the net effect of natural disasters on long run growth is positive or negative depends on how the recovery progresses after the disaster, where the disaster occurs, and the type of disaster that occurs. The theoretical discussion supports the empirical evidence collected by Skidmore and Toya; natural disasters can increase or decrease long run growth depending on the circumstances.

Sound institutions help ensure a healthy recovery following a disaster. A healthy recovery helps maximize the positive effects and minimize the negative effects of disasters on the important

macroeconomic variables. Also, sound institutions decrease the chance of a financial crisis following the disaster and should minimize the shock to the population, both of which could harm long run growth. Since institutions and growth are symbiotic, countries cannot realistically improve their institutions overnight. They are constrained by the amount of resources that they can put towards improving institutions. Still, any effort to improve institutional efficiency following a disaster should aid recovery efforts and yield benefits in the long run.

Relatively mild disasters that occur over a small area in large countries have little effect on long run growth in large countries, but the same disaster in a small country could decimate the economy of the small country. Montserrat provided an example of a country facing a such a disaster. The Soufriere Hills volcanic eruptions were not massive, but the size of the island ensured that the long run implications of the eruption were significant. Any type of disaster, so long as it has devastating effects on a local scale and prevents recovery, could have the same long run effects as the Soufriere Hills volcanic eruptions.

The empirical evidence from Skidmore and Toya showed that the type of disaster that occurred had a significant effect on whether the effect of natural disasters long run growth was positive or negative. Their evidence also showed that the link between climatic disasters and long run growth was positive and that the link between geologic disasters and long run growth was negative (though not consistently) across the countries they studied. The exact reasons for the differences are unclear. Their evidence showed that the positive effects on human capital accumulation and total factor productivity, a crude measure of the technology embodied in capital, from climatic disasters were higher than for geologic disasters. It is possible that geologic disasters have a greater effect on the infrastructure of a country, which would hamper initial recovery efforts. While a drought is a type of climatic disaster, the theoretical discussion and some historical evidence implied that droughts have a predominantly negative impact on long run growth, except possibly in countries that diversify their economies. Further studies using Skidmore and Toya's data or other sources of data on disasters would help economists further pin down the effects of different types of natural disasters in the long run.

Considering that there is only one source of in depth empirical data concerning the effect of natural disasters on long run growth, an effort to develop a more precise data set for natural disasters and their

economic effects would be worthwhile. Specifically, Skidmore and Toya's analysis does not take into account differences in insurance across countries, which they admit could affect the results of their analysis [Skidmore and Toya, 2002, 682]. They do not take into account droughts, which have significant effects when they strike less developed countries. With more precise data, economists could further analyze the effects of disasters on growth and empirically determine the impact of droughts on long run growth.

For now, focusing on recovery efforts after natural disasters appears to be the most effective means by which countries and international organizations can encourage long run growth following a natural disaster. Since the relationship between growth and institutions is symbiotic, countries cannot physically move or change their size, and countries cannot choose the disasters that affect them, the only way by which countries can increase the likelihood that disasters will increase long run growth before the disasters strike is to prepare for the disasters. Efficient preparation can affect long run growth in several ways. Countries that prepare for disasters should have a smoother recovery effort. Efficient preparation would also include provisions in the government budget for emergency funding after a disaster, which would reduce the chance of a financial crisis. With a plan to keep commodity prices low following a disaster, provisions for emergency funding will reduce the probability that inflation will occur. Preparation on the community level will emotionally prepare people for the trauma associated with natural disasters and give them means by which they can help themselves. Psychologically, they will be more prepared for the disaster and will not suffer as much from the stress following the disaster. In short, planning for the next disaster benefits long run growth in multiple ways. Governments and relief agencies should continue to emphasize recovery after a disaster, and they should prepare for disasters before they happen.

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