ARE NATURAL DISASTERS A SUBSTANTIAL REASON FOR TECHNOLOGICAL INNOVATION AND ECONOMIC DEVELOPMENT? CROSS-COUNTRY ANALYSIS

by

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Abstract

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Recent studies found different effects (both positive and negative) of natural disasters on economic growth after combining for other determinants. These results and increasing number of natural catastrophes are drawing our attention to the field of Economics of Natural Disasters. The present paper focuses on the Research and Development Expenditures as the pathway through which natural disasters affect economic growth. The main hypothesis is that natural disasters provide opportunities to adopt new technologies and lead to increasing research expenditures which in turn leads to fast economic growth due to boom in construction and modern infrastructure and technology. The results of cross-country panel data regressions indicate that natural disasters have positive and significant effect on country's R&D expenditures and GDP growth. A country whose capital stock is reduced by natural disasters has an incentive to replace it with the capital which has newer technology.

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GLOSSARY

Estimated Damage Costs (EDC). The economic impact of a disaster usually consists of direct (e.g. damage to infrastructure, crops, housing) and indirect (e.g. loss of revenues, unemployment, market destabilisation) consequences on the local economy.

Research and Development expenditures (R&D). Current and capital expenditures (both public and private) on work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development.

Gross fixed capital formation. Shows how much of the new value added in the economy is invested rather than consumed.

Government final consumption. All government expenditures for purchases of goods and services (including compensation of employees).

Domestic credit to private sector. Financial resources provided to the private enterprises.

C h a p t e r 1

INTRODUCTION

Natural disasters are associated with significant economic and social costs. Over the period 1975-2011 the estimated damage caused by natural disasters reached $350 billion, and the number of killed people increased to 120 million in 2011 (Figures A1 and A2 in Appendix A). Economists started to measure the effect of natural disasters on economic growth after Dacy and Kunreuther (1969) had published a book "The Economics of Natural Disasters". Dacy and Kunreuther (1969) provide theoretical analysis of disasters and their impacts on economy and outline challenges and fields for further empirical research.

However, the effect of natural disasters on economic growth still remains unclear. Natural disasters result in economic "shock" primarily because of their impact on firms' productivity and the need for reconstruction and relief. On the other hand, post-disaster technological innovation may reduce damage caused by natural disasters and promote further growth in productivity and income per capita. Important research question arises: "Can natural disasters stimulate industrial research and development for further economic growth through country's support for R&D in high-technology, knowledge-intensive areas?"

After a disaster occurs government and private companies assign money for reconstruction (to build new seismic-stable houses and modern innovative factories, which have been destroyed by hurricane for instance). It provides research and development expenditures increase because new technologies and innovations must be considered for creation of new methods of production or new basis for houses construction. As Skidmore (2008)[1] said: "When something is destroyed you don't necessarily rebuild the same thing that you had. You might use updated technology. You might do things more efficiently".

There are a lot of examples which clearly demonstrate the importance of R&D expenditures as a link between natural disasters and economic growth. For instance, Kawai and Morgan (2012) study The Great East Japan Earthquake (Tohoku, 2011)[2] and possible growth strategies after this disaster. They propose a long-term strategy for overcoming disaster consequences and putting the Japanese economy on "a stable growth path" by supporting R&D in different areas (service sectors, agriculture, energy sector etc.). They predict positive impact of R&D expenditures and reconstruction investment. It results in Japanese economic recovery and growth which can be visible in 2012. Now it is difficult to sound positive about the Hurricane Sandy's (October 2012, USA) consequences. But one great benefit for USA can be the Stafford Act – the United States federal law designed to bring federal natural disaster assistance for state and local governments in carrying out their responsibilities to aid citizens and rebuild infrastructure. It can be said that the USA has a program for motivation of R&D expenditures and reconstruction after disasters. That is why R&D expenditures represent the link between natural disasters and economic growth through technological innovation. Of course, black plague, Spanish influenza and World Wars are not in the category of natural disasters but they can serve as an example of catastrophes which led to huge social and economic upheavals.

This research is intended to fill the gap in the field of Economics of Natural

[1]Skidmore M. (2008) How disasters help. Web source: http://www.boston.com/bostonglobe/ideas/articles/2008/07/06/how_disasters_help/?page=ful

[2]The k2p blog opinions on Energy, Electric Power, Climate and Environment. Could the disaster in Japan power a wave of sustainable growth? March 20, 2011. Web source: http://ktwop.wordpress.com/tag/economic-growth/

Disasters by testing the working hypothesis whether natural disasters provide opportunities to adopt new technologies and lead to increasing research expenditures and establishing programs of possible disaster mitigating or even preventing. This can lead to fast economic growth due to boom in construction and modern infrastructure and technology. That is why R&D expenditures are interpreted as a pathway, through which the effect of natural disasters on economic growth can be examined. This question has not been addressed by any other work before.

Research and Development expenditures per capita (R&D, $US) is the main variable of interest. Expenditures for research and development are current and capital expenditures (both public and private) on work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development (definition provided by the World Bank Glossary). In addition to regular predictors of R&D identified in the previous literature I also control for Estimated Damage Costs (EDC, $US) and Natural Disasters variables (frequency of droughts, earthquakes, floods and storms).

In the paper the annual data for 38 countries over the period 1996-2007 are used. The panel is unbalanced. I use World Bank classification of the countries and divide them into two groups: developed and developing to capture heterogeneous effects of natural disasters on R&D expenditures and economic growth.

The econometric model which is used is a fixed-effects model. I also control for cross-sectional differences by dividing countries on developing and developed (advanced), and measure storm, earthquake, flood and drought strikes by their intensity (moderate or severe).

The data on natural disasters used for the estimation are obtained from the International Disaster Database ((EM-DAT). Data on Research and development expenditures are taken from the OECD Main Statistics and Technology Indicators database. Data on other explanatory variables are taken from the World Bank (World Development Indicators (WDI) and Journal of Applied Econometrics data archive.

I find that some natural disasters can have positive impact on economic growth of the country. Results are indicating that R&D expenditures are increasing in presence of natural disasters. This increase is bigger for developing countries. Thus, a country whose capital stock is reduced by natural disasters has an incentive to replace it with the capital which has newer technology.

The rest of the paper is structured as follows. Chapter 2 contains literature review, in Chapter 3 estimation model is developed and methodology is explained, Chapter 4 contains description of the data used for the analysis, Chapter 5 reports the results of the estimation and Chapter 6 concludes.

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LITERATURE REVIEW

The literature review is divided into two main parts. The first one considers two opposing strands of literature concerning the impact of natural disasters on economic growth. The second part includes studies which investigate different opportunities to update the capital stock and adopt new technologies after a disaster occurs.

2.1 Different effects of Natural Disasters on Economic Growth

The pioneering work in the field of Economics of Natural Disasters belongs to Dacy and Kunreuther (1969). They provide theoretical background for the disaster related research and construct a unique theoretical framework for further empirical studies. They claim that in the long-run technological progress becomes the driving force of economic growth. The authors use a simplified version of the Solow-Swan growth model with exogenous shock (disaster) and endogenous level of technology available for replacement. They say that disaster insurance today can be interpreted as savings for the future and can lead to faster recovery and rebuilding that brings economy back to its pre-disaster level.

Some economists have found negative effects of disasters on economic growth (Albala-Bertrand, 1993), while others – positive (Skidmore and Toya, 2002), Hallegatte and Dumas, 2009, Fomby et al., 2011). Their conclusions vary mostly due to such factors: period of time (some studies examined short-run economic growth and others – long-run), type of disaster (severe or moderate), economic sector, and whether the country is developed or developing. But we cannot say for sure what effects these factors have on research and development expenditures after a disaster occurs, without empirical investigation. For example, flood can positively affect agriculture sector growth, because irrigated ground will lead to a larger harvest in the future. Or, earthquakes lead to building new and more efficient infrastructure which leads to more productive economy in the long run.

The first macroeconomic model of the impact of natural disasters on long-run economic growth is constructed by Albala-Bertrand (1993). The main result: "natural disaster is unlikely to have a long-term impact on growth". The model is applied to a sample of large Latin American disasters occurring in the 1970-1980th. The author shows that even large disasters do not have significant impact on economic growth and response requires minimum compensatory investment. Later, Jaramillo (2007) takes a deeper look at the relationship between natural disasters and economic growth in the short-run and long-run periods, providing some critics to Albala-Bertrand's (1993) work. Using a panel data regression with fixed country effects and year-dummies, and controlling for trade openness and foreign aid, he tests for the effect of a disaster on current and next-year GDP growth (short-run effects) and for cumulative effects of disasters (long-run effects). Contrary to Albala-Bertrand's (1993) research, large natural disasters appear to have persistent effects on the GDP growth in 1960-1996. The effects range from positive to negative depending on size of the country and type of a disaster.

In addition to the studies which obtain results on negative or controversial effect of natural disasters on economic growth, there is a growing literature demonstrating the positive effects of natural disasters. Skidmore and Toya (2002) provide a theoretical discussion about natural disasters' influence on economy and use cross-country analysis (1960-1990) to examine the possible connection between natural disasters, investment decisions, total factor productivity (TFP) and long-run economic growth. They group natural disasters into climatic and geologic ones and make conclusion that climatic disasters are positively correlated with economic growth, human capital investment and growth in TFP, but geologic disasters are negatively correlated with economic growth. Hallegatte and Dumas (2009) in turn claim that when a natural disaster damages productive capital (factories, houses, bridges), the destroyed capital can be replaced using the most recent technologies, which have higher productivities. Capital losses can be compensated by a higher productivity of the economy after disaster occurs which represents a positive consequence of disasters.

Most relevant paper for this work is written by Fomby et al. (2011). The authors take panel (94 countries) data for the period 1960-2007 and study the effects of different types of disasters (floods, storms, droughts, earthquakes) on economic sectors' middle-run growth (agricultural, industrial, service sectors). They run four linear regressions with four different dependent variables: GDP per capita growth, Agricultural sector growth, Industrial sector growth and Service sector growth. The authors find evidence that some disasters may have positive effects on economic growth in different economic sectors. For example, "floods tend to have a positive effect on economic growth and the response of agricultural growth is significantly positive 1 year after but not on the same year of the event" (Fomby et al., 2011). The type of a disaster and country development also matter. For instance, the effects of natural disasters are stronger on developing than on developed countries.

Summing up, when compared to the short-run research, the literature on the long-run effects of natural disasters is limited and its results inconclusive. One reason for the scarcity of research in this area is the difficulty of understanding what would have happened to the path of GDP growth if natural disasters had never occurred? This is still, in scientists' view, a very promising area to study.

2.2 R&D and Natural Disasters

Another growing body of work in the field of economics of natural disasters deals with the allocation of government funds for Research and Development expenditures (R&D). Appropriate allocation will lead to reducing the damage of disasters, improving understanding of, preparation for, and response to natural disasters.

For example, Cuaresma et al. (2008) study the impact of catastrophic risk on technology transfer to developing countries. The authors claim that countries can effectively and quickly recover from natural disasters' shock, update the capital stock and adopt new technologies if they trade with developed countries. Hence, R&D stock can be treated as exogenous factor and countries gain access to foreign technologies through trade after a disaster occurs. The authors use cross-country gravity equations with natural disasters frequency and intensity. "Technology importing economies" are G-5 countries (France, Germany, Japan, the United Kingdom, the USA). The sample includes 49 developing countries. And the main conclusion: only developed countries benefit from "capital upgrading through trade after a natural catastrophe". Okuyama (2003) and Okuyama, Hewings, and Sonis (2004) find that replacement of older equipment by increasing of R&D expenditures leads to positive productivity shock and economic growth. This happens because older equipment is more subjected to damage when a disaster occurs and destroys capital stock.

If we consider specific examples of disasters and economic reconstruction after them, one recent work should be mentioned. Hayashi (2012) examines two big Japan's earthquakes: Kobe (1995) and Tohoku (2011). He considers post-disaster reconstruction process in Kobe to draw lessons for Tohoku. The author provides policy analysis and reconstruction efforts description, which help to understand better how the government reacts when a disaster occurs on the examples of two earthquakes in Japan. There is no empirical model in the paper but using available country's statistics and simple calculations the author shows that disasters create an opportunity to build better communities and economies. What seems to be needed is a political (government) effort, private investments in production and employment, and public investments in infrastructure.

For Honda, 2011 was a very challenging year because of the Great East Japan Earthquake and flooding in Thailand. Experts in Honda company presented a report on effective recovery efforts which lead to innovation: "Feature: Natural Disasters and Energy issues" (2012)[1]. They implement Post-Disaster Reconstruction Project at the Tochigi R&D Center. It includes activities on the rebuilding and redesigning the center's heavily damaged buildings and facilities. For instance, they establish more efficient technologies such as: "new state-of-the-art lighting and air conditioning systems", which help decrease energy costs and raise company's environmental performance. Honda's actions may serve as an example of the company that wants to evolve, not just return to former working conditions which in turn help to improve company's productivity and economic growth of the country.

One more example of successful reconstruction activities is presented in the report prepared by the World Bank (2008). The authors establish effective systems for recovery and reconstruction in the response to disaster. The report contains six case studies on Guatemala, Haiti, Indonesia, Mozambique, Pakistan and Sri Lanka. In each country new systems on disasters prevention, mitigation and reconstruction have been developed to highlight the importance of ex ante disaster management for countries at

[1] Feature: Natural Disasters and Energy issues. Honda Company Report. (2012) Webresource:http://world.honda.com/environment/report/download/2012/2012_report_E_04.pdf

risk. The authors show on example of these 6 countries, how technical and institutional innovations after disaster lead to stable economic growth.

Despite of the previous research which studies different effects of natural disasters on economic growth, relatively little attention has been paid to the pathways through which this effect arises. One of such pathway is the R&D expenditures.

Thus, in terms of theory and methodology, this paper is the most connected to works by Fomby et al. (2011) and Cuaresma et al. (2008). But it adds to the literature examining how natural disasters affect R&D expenditures and how this effect constitutes with post-disaster economic growth and development. This work provides a piece of empirical research in a disaster related field, but there is still a large space to be filled and a long way to fully understand "Economics of Natural Disasters", where a lot of theoretical and empirical challenges are left.

Chapter 3

METHODOLOGY

The main question of the paper is whether R&D expenditures represent the link between natural disasters and economic growth through increase in technological innovation. To tackle this issue several regression specifications are adopted.

The main model shows how adding the number of Natural Disasters (ND) variables and Estimated Damage Costs (EDC) variable change the effect of R&D per capita on GDP per capita. It can be shown by adding EDC and number of Natural Disasters (ND) as independent variables to the GDP equation (Equation 1). Country fixed-effects model is estimated using specification, adopted by Fomby et al. (2011) and classical GDP growth equation specification adopted by Mankiw, Romer and Weil (1992):

$$\ln(GDP_{i,t}) = \alpha_i + \beta_o z_{i,t} + \beta_1 \ln(R\&D_{i,t}) + \beta_2 \ln(EDC_{i,t}) + \beta_3 x_{i,t} + \xi_{i,t}, \quad (1)$$

where country index is i=1, 2, . . . , N and the time index for country i is t = 1, . . .,T_i. Equation 1 is applied to two different groups of countries: developing countries and developed (advanced) countries. Coefficient α_i - the fixed effects for each country. Dependent variable is real GDP per capita (in logs). The 5 × 1 vector $z_{i,t}$ represents (i) trade openness ((exports+imports)/GDP), (ii) gross fixed capital formation (as share of GDP), (iii) the growth rate of government consumption expenditure (as share of GDP), (iv) domestic credit to private sector (as share of GDP), (v) labor force with secondary education (as share of total population), i.e.:

$$z_{i,t} = \begin{bmatrix} Trade\ Openness_{i,t} \\ Gross\ Fixed\ Capital\ Formation_{i,t} \\ Government\ Final\ Consumption_{i,t} \\ Domestic\ credit\ to\ private\ sector_{i,t} \\ Labor\ Force\ with\ Secondary\ Education_{i,t} \end{bmatrix}$$

We use the logs of these variables because of the variance stabilizing characteristics of the log transformation and very straightforward interpretation of the results, namely percentage change.

According to Mankiw, Romer and Weil (1992) who provide empirical estimation of Solow growth model and test predictions of the Solow's model, four main variables enter Equation 1: Gross fixed capital formation, Government final consumption, Domestic credit to private sector and Labor force with secondary education. Gross fixed capital formation shows how much of the new value added in the economy is invested rather than consumed [1]. Government final consumption variable represents all government expenditures for purchases of goods and services (including compensation of employees)[2]. Domestic credit to private sector refers to financial resources provided to the private enterprises[3]. Variable Labor force with secondary education represents the human capital variable and it shows the total number of economically active population (age 15 and older) with secondary education as a share of total population.

Fomby et al. (2011) use Trade Openness variable as explanatory in estimation of effects of natural disasters on economic growth. According to authors, Trade Openness is an exogenous variable which varies across countries due to countries' characteristics (more imports or exports) which determine the effect on country's GDP and on other independent variables.

1 http://en.wikipedia.org/wiki/Gross_fixed_capital_formation
2 http://data.worldbank.org/indicator/NE.CON.GOVT.ZS
3 http://data.worldbank.org/indicator/FS.AST.PRVT.GD.ZS

We need to include such factor as Trade Openness because it affects the other variables which are presented in the equation, i.e. investment or government consumption. Omitting it can lead to estimation bias (Forni and Reichlin, 1998).

The 4×1 vector $x_{i,t}$ in the Equation 1 represents the four types of disaster variables: drought, earthquake, flood and storm:

$$x_{i,t} = \begin{bmatrix} Drought_{i,t} \\ Earthquake_{i,t} \\ Flood_{i,t} \\ Storm_{i,t} \end{bmatrix}$$

Variables in the vector $x_{i,t}$ represent frequency of natural disasters occurrence in one country for one year. But in order to measure economic impact of natural disasters in terms of direct (e.g. damage to infrastructure, housing) and indirect (e.g. unemployment and loss of revenues) costs Estimated Damage Costs (EDC) variable is also included into the Equation 1. Estimated Damage from natural disasters is actively used in different research papers to present effects of natural disasters, for example, see Pielke (1998) and Collins (2001)[1].

Estimated Damage from natural disasters should be normalized and inflation adjusted (see Equation 2). The framework employed by Pielke et al. (1998) is used:

$$NormalizedDamage_t^s = DamageCost_t \times \frac{GDPdeflator_s}{GDPdeflator_t} \times \frac{Population_s}{Population_t} \times \frac{WealthPerCapita_s}{WealthPerCapita_t} \quad (2)$$

[1] Collins, D. J., and Lowe, S. P. 2001. A macro validation dataset for U.S. hurricane models, Casualty Actuarial Society Forum, Casualty Actuarial Society, Arlington, Va., http://www.casact.org/pubs/forum/01wforum/01wf217.pdf.

where *s* – the (chosen) year one wishes to normalize to (*s*=2000), *t* – the year in which damage occurred, the gross domestic product (GDP) deflator adjusts for inflation (i.e., change in producer prices), while the remaining two correction factors adjust for changes in population and wealth per capita (Pielke et al. (1998), Neumayer and Barthel (2011)). There are different ways to measure the wealth per capita, i.e. use data on the value of capital stocks. Often, researches use GDP per capita due to lack of data. In this work GDP per capita used to measure the wealth per capita. Data for Inflation (GDP deflator), Population and GDP per capita are taken from the World Bank (World Development Indicators (WDI).

Gross domestic R&D expenditures variable shows the sum of R&D expenditures in the following economic sectors: business, university, government and non-profit[1] (Godin, 2003). The real R&D expenditure is computed by deflating the retail price index (2000=100). In order to get R&D expenditures per capita, gross R&D expenditures should be divided by country's population.

To prove the initial hypothesis, we need to compare coefficients on R&D, Natural Disasters variables and EDC variable from the Equation 1 with coefficients on R&D, ND variables and EDC from general specifications which show direct effect of: 1) R&D per capita on GDP per capita; 2) ND and EDC on GDP per capita. We expect coefficient on R&D from the Equation 1 be bigger compared to coefficient on R&D from the direct estimation of R&D on GDP per capita and coefficient on EDC be negative and significant compared to the direct estimation of EDC and ND on GDP per capita. Some coefficients on ND variables should be significant but they can have different signs as it was discussed in the literature review section

[1] The measure includes R&D funded from abroad but excludes payments made abroad.

above. For example, Fomby et al. (2011) obtained in their paper that floods can have positive effects on economic growth.

Several econometric problems may arise and should be discussed. First, it is data collection issue. Not all countries have data for all years that is why we have unbalanced panel. Moreover, data on R&D expenditures and EDC are present not for all countries and for many countries there is only one observation for one year so there is no point to include them into fixed effects regression and we need to drop them. It leads to a small sample and to the sample selection problem (selection of countries in not random, it depends on the availability of data). Second, problem of heteroskedasticity which makes standard errors to be biased. Third, serial correlation test should be applied. However, this test usually applied to macro panels with long time series (over 20-30 years). We have 11 years panel data. Serial correlation causes the standard errors of the coefficients to be smaller than they actually are and R-squared higher. Standard Errors are robust to disturbances being heteroscedastic and autocorrelated if we use "cluster" option in Stata fixed effects regressions. Fourth, endogeneity problem. R&D and GDP may have causal relationship. We need to test R&D variable for endogeneity using Durbin-Wu-Hausman test. There is no such problem with other variables of interest because natural disaster variables represent exogenous shocks to the economy.

C h a p t e r 4

DATA DESCRIPTION

We have annual data for 11 years (1996-2007) for 38 countries. Panel is unbalanced. The data on natural disasters are obtained from the Emergency Disasters Database (EM-DAT)[1], maintained by the Centre for Research on the Epidemiology of Disasters (CRED). EM-DAT distinguishes two generic categories for disasters (natural and technological). The natural disaster category is divided into 5 sub-groups which in turn cover 12 disaster types and more than 30 sub-types. In the paper droughts, earthquakes, floods and storms are used in natural disaster category as subject of analysis. Descriptive statistics of natural disasters variables is provided in the Table 1.

Table 1. Descriptive statistics of natural disasters variables

Variable	Observations	Mean	Std.Dev.	Min	Max
Drought	140	0.02	0.15	0.00	1.00
Earthquake	140	0.07	0.28	0.00	2.00
Storm	140	0.16	0.40	0.00	2.00
Flood	140	0.36	0.66	0.00	4.00

For a disaster to be entered into EM-DAT, at least one of the following criteria must be fulfilled: 10 or more people reported killed; 100 or more people reported affected; declaration of a state of emergency; call for international assistance. The database describes the dates and the types of natural disasters (e.g. drought, flood). For each disaster event, the number of fatalities (persons confirmed as dead, missing, and presumed dead), the number of people injured, needing immediate assistance for shelter (referred to "homeless"), and affected are reported. People affected are those

[1]The International Disasters Database (EM-DAT). Natural Disasters Trends. Web resource: http://www.emdat.be/natural-disasters-trends

requiring immediate assistance during a period of emergency. People reported injured or homeless are aggregated with those affected to produce the total number of people affected (referred to “total affected”).

There is no standard procedure for estimating the cost of disaster. For variable “Estimated damage costs from natural disasters” data from the International Disaster Database (EM-DAT)[1] were used and the method of estimating the damage costs providing by EM-DAT. The economic costs of a disaster usually consist of direct (i.e. damage to infrastructure, crops, housing) and indirect (i.e. loss of revenues, unemployment) costs which affect the local economy. This variable is representing the total effect of natural disaster on country’s economy comparing with frequency of natural disasters. In EM-DAT estimated damage is given in US$ (in thousands). For each disaster, the registered number corresponds to the damage value at the moment of the event (to the year when disaster occurs). It is then normalized using 2000 as base year.

Figure 1 shows the total R&D expenditures statistics by country for 2001 or first available year and for 2010 of latest available year[2]. In 2010, R&D expenditures reached 2.3% of GDP for the OECD countries in comparison with 0.6% and 1.1% of GDP for Poland and Russian Federation respectively. Ukraine does not enter this statistics, but from the World Bank statistics, R&D expenditures decreased in Ukraine from 1.1% of GDP in 2003 to 0.9% of GDP in 2009. The highest R&D intensity of 4.25% of GDP is in Israel.

[1] http://www.emdat.be/

[2] Source: OECD Factbook 2011-2012: Economic, Environmental and Social Statistics

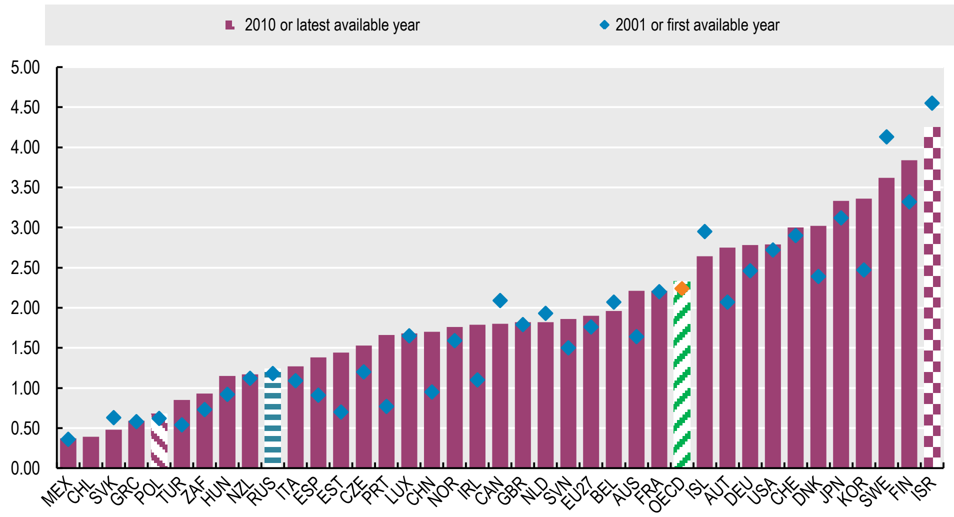

Figure 1. R&D statistics by country (% of GDP)

Figure 2 shows correlation between EDC (in logs) and gross R&D (in logs) for different countries in 1998, 2001, 2004 and 2006 years. It is not surprisingly, that the highest values of EDC and R&D expenditures are in Japan for almost all years.

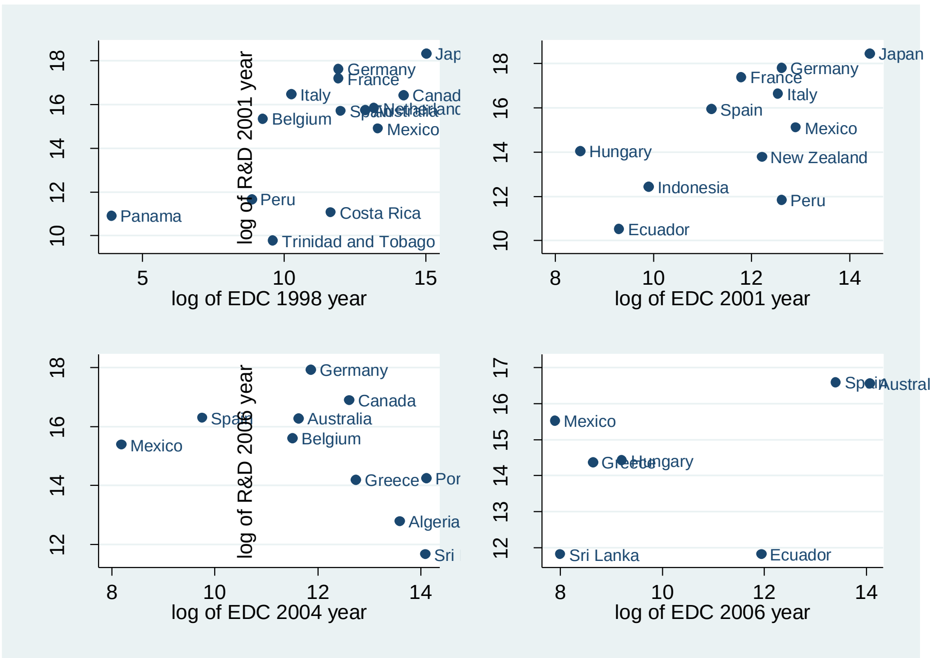

Figure 2. Scatterplots: log of EDC and R&D for 1998, 2001, 2004, 2006

Descriptive statistics for key determinants of GDP per capita is provided in Table 2. The data on: Gross fixed capital formation, Trade openness, General government final consumption expenditure, Domestic credit to private sector (financial depth) are taken from Fomby's et al. (2011) paper (publicly available at Journal of Applied Econometrics data archive). There are data for 1960-2007 but with missing values. The data on Growth rate of real GDP per capita, Labor force with secondary education are taken from the World Bank (World Development Indicators (WDI)). The data on Research & Development Expenditures are taken from the OECD Main Statistics and Technology Indicators database.

Table 2. Descriptive statistics of key variables

Variable	Obs.	Mean	Std.Dev.	Min	Max
Log of real GDP per capita	140	10.54	1.98	4.31	15.75
(Exports+imports) /GDP (in logs)	140	-0.45	0.45	-1.66	0.49
Gross fixed capital formation/GDP (in logs)	140	-1.55	0.15	-2.09	-1.10
Domestic credit to private sector/GDP (in logs)	140	-0.49	0.76	-2.43	0.84
Growth rate of general government final consumption expenditure/GDP	140	0.00	0.04	-0.16	0.16
Labor force with Secondary Education (% of Total Population)	140	37.47	15.90	10.10	68.10
log of real R&D Expenditures per capita	140	-2.11	1.72	-6.73	0.15
log of EDC	140	11.89	2.60	3.40	16.43

It should be noted, that the main drawback of the existing dataset is its small size. Data on natural disasters is available only for countries in which they are occurred. Also, data for R&D expenditures are presented not for all years and not for all countries which leads to the small sample. Only countries for which estimated damage costs are known were considered in the analysis. Thus the selection of countries was not random which may lead to sample selection bias. All countries which are present in the analysis are in the Table 3.

Table 3. List of Countries in the sample

Algeria	Japan
Argentina	Madagascar
Australia	Mexico
Austria	Morocco
Belgium	Netherlands
Bolivia	New Zealand
Brazil	Pakistan
Canada	Panama
Chile	Peru
Colombia	Philippines
Costa Rica	Portugal
Denmark	Spain
Ecuador	Sri Lanka
France	Sweden
Germany	Switzerland
Greece	Trinidad and Tobago
Hungary	Urugway
Iceland	
India	
Indonesia	
Italy	

Countries were classified as developed and developing using World Bank Classification. The World Bank's main criterion for classifying economies is gross national income (GNI) per capita. Based on its GNI per capita, every economy is classified as low income, middle income (subdivided into lower middle and upper middle), or high income. Other analytical groups based on geographic regions are also used[1]. Developed and developing countries in the sample are presented in Table 4. Descriptive statistics for Developing and Developed countries is presented in Tables B1 and B2 respectively (Appendix B).

Table 4. Developed and Developing Countries in the sample

Developed Countries	
Australia	Italy
Austria	Japan
Belgium	Netherlands
Canada	New Zealand
Denmark	Portugal
France	Spain
Germany	Sweden
Greece	Switzerland
Hungary	
Iceland	
Developing Countries	
Algeria	Mexico
Argentina	Morocco
Bolivia	Pakistan
Brazil	Panama
Chile	Philippines
Colombia	Sri Lanka
Costa Rica	Urugway
Ecuador	Trinidad and Tobago
India	Peru
Indonesia	
Madagascar	

To understand how developed and developing countries which presented in Table 4, are different in terms of economic growth, R&D expenditures and EDC, please see Figures 3, 4 and A3 , A4 (Appendix A). Figure 3 presents scatterplots of the GDP per capita (in logs), R&D per capita (in logs) and EDC (in logs) for 1996-2007 years and for developing/developed countries in the sample. We see that there is growth in GDP and R&D in spite of

[1] The World Bank Classification. Web source: http://data.worldbank.org/about/country-classifications

occurrence of natural disasters in developed countries. Of course, developing countries are more dependent on such exogenous shocks as natural disasters. From Figure 4 we can say that the most differences between countries occur in terms of natural disaster variable (Estimated Damage Costs).

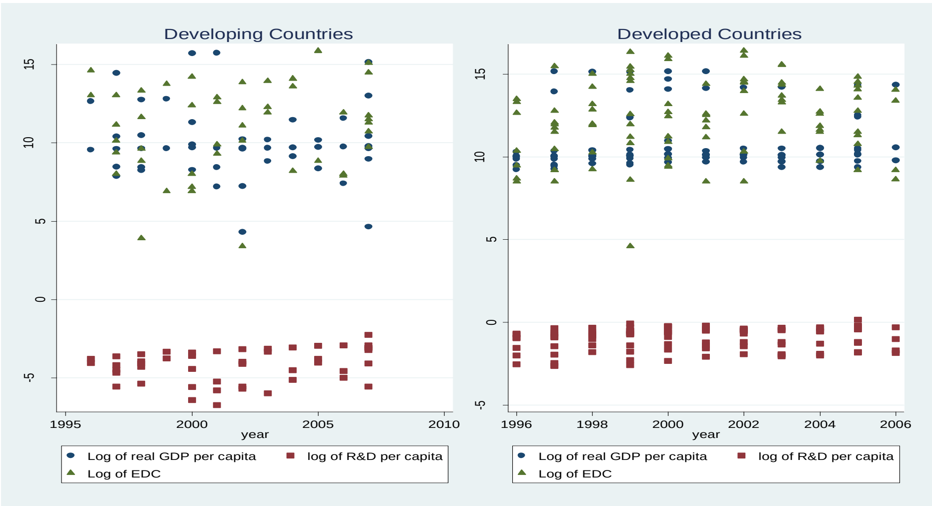

Figure 3. Linear relationship between log of R&D, EDC and GDP

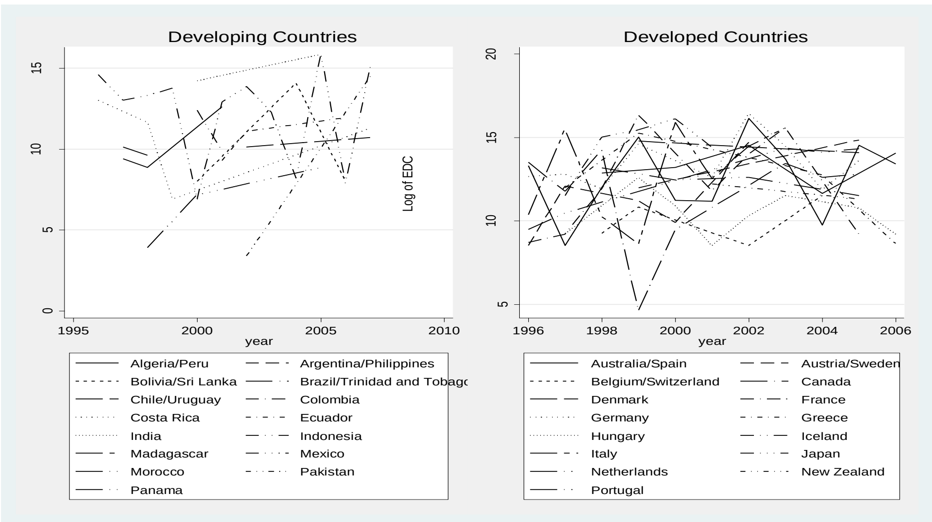

Figure 4. Panel data line plot of log of EDC for Developed and Developing Countries

C h a p t e r   5

RESULTS AND DISCUSSION

5.1 Benchmark Results

This section contains empirical estimates of effects of natural disasters on R&D expenditures and Economic growth.

Table 5 reports the estimated coefficients from the Equation 1 (column 1 in the table) and two benchmark cases discussed above: effect of EDC and ND on GDP (column 2) and effect of R&D on GDP (column 3). We can see that adding natural disasters variables increases coefficient on R&D and leads to GDP per capita increasing compared to regressions where only R&D expenditures or natural disaster variables are included. It proves our initial hypothesis that after disaster occurs, R&D expenditures increase which in turn leads to economic growth. If R&D expenditures increase by 1%, we would expect GDP per capita to increase by approximately 0.234% (see column 3, Table 5). With the presence of natural disaster variables we obtain the following results: if R&D expenditures increase by 1%, we would expect GDP per capita to increase by approximately 0.24% (see column 1, Table 5). Moreover, coefficients on EDC and storm become significant at 10% and 5% respectively compared to the results in column 2, Table 5. Coefficient on drought becomes significant at 1%. All natural disaster variables have negative direct impact on GDP per capita. After they occur, part of the capital goes for reconstruction. Government and private companies assign more money on R&D to rebuild destroyed houses and factories using new technology. New factories become more productive which in turn leads to increase in real GDP per capita.

Table 5. EDC, ND and R&D per capita: impact on GDP per capita

Impact on log of GDP per capita	(1) R&D,EDC and ND	(2) EDC and ND	(3) R&D
log of R&D per capita	0.240***		0.234***
	[0.023]		[0.026]
Log of EDC	-0.003*	0.002	
	[0.002]	[0.002]	
drought	-0.091***	-0.095**	
	[0.026]	[0.046]	
earthquake	-0.015	-0.011	
	[0.019]	[0.025]	
storm	-0.026**	-0.029	
	[0.010]	[0.031]	
flood	0.001	-0.005	
	[0.005]	[0.014]	
(Exports+imports)/GDP (in logs)	0.110**	0.290***	0.123**
	[0.041]	[0.105]	[0.049]
Gross fixed capital formation/GDP (in logs)	0.025	0.187	0.070
	[0.073]	[0.142]	[0.080]
Domestic credit to private sector/GDP (in logs)	0.036	0.133**	0.038
	[0.024]	[0.058]	[0.029]
Growth rate of general government final consumption expenditure/GDP	0.191	-0.195	0.171
	[0.125]	[0.138]	[0.190]
People with Secondary Education (% of total)	0.002*	0.004	0.000
	[0.001]	[0.003]	[0.001]
Constant	11.120***	10.873***	11.199***
	[0.129]	[0.264]	[0.141]
Observations	140	140	140
R^2	0.862	0.518	0.835
Adjusted R^2	0.851	0.481	0.828
Fixed Effects	Yes	Yes	Yes

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Obtained results on impact of R&D expenditures on GDP are comparable to other studies. For example, Ulku (2004), using 30 countries and 285 observations, finds that GDP will increase by approximately 0.20% if R&D expenditures increase by 1%. Also, model specification: the fixed-effects regression analysis is employed by Ulku (2004) and Fomby et al. (2011). It accounts for country fixed effects and yields consistent estimators of the coefficients[1]. So, we can say that coefficient on R&D is statistically and economically significant.

Table B3 in Appendix B reports the estimated coefficients from Equation 1 for developing countries in the sample. This model gives the following results: in the presence of natural disaster variables, if R&D expenditures increase by 1%, we would expect GDP per capita to increase by approximately 0.232% compared to 0.231% without natural disasters. It means that developing countries invest more in new technology after old factories and houses were destroyed. It causes R&D expenditures increasing and that is why leads to faster GDP per capita growth. Drought and storm have negative and significant impact on real GDP per capita.

The estimated coefficients from Equation 1 for developed countries in the sample are reported in Table B4 (Appendix B). This model gives the following results: in the presence of natural disaster variables, if R&D expenditures increase by 1%, we would expect GDP per capita to increase by approximately 0.267% compared to 0.257% without natural disasters. But coefficients on natural disasters in Column 1, Table B4 are insignificant. It can be explained by the fact that developed countries as usual have a special programs or systems for fast reconstruction after natural disasters which allows them to respond better. So, developed countries are able to recover soon and they can be characterized by stable economic growth. Furthermore, economic growth fluctuates and recovers so substantially that the effect of natural disasters for developed countries is almost zero and statistically insignificant (results are comparable to Fomby et al. (2011)).

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[1] Provided that there is no endogeneity problem and the lagged dependent variable is not included in the analysis.

Fomby et al. (2011) point out that the impact of moderate disasters and extremely severe disasters on the economic performance differs in their magnitude and dynamic characteristics. To see how effects of natural disasters variables differ due to their intensity we divide them into moderate and severe, using framework employed by Fomby et al. (2011). Moderate disasters (estimated in Equation 1): if intensity > 0.0001[1], for severe disasters: if intensity > 0.01). Value of $intensity^k_{t,i,j}$ measures the magnitude of the natural disaster (k=1 if drought, k=2 if flood, k=3 if earthquake, k=4 if storm) relative to the size of the economy. The natural disaster is moderate if the sum of the number of fatalities ($fatalities^k_{t,i,j}$) and 30% of the total number of people affected ($total\ affected^k_{t,i,j}$) is greater than 0,0001% of the population (framework employed by Fomby et al., 2011)). For severe disasters Fomby et al. (2011) set the threshold 1% of population (0,01). Remember that for moderate disasters it was 0,0001% of the population. Then, we must obtain the value of $ND_{i,t}(k)$. For each type of disaster, variables $intensity^k_{t,i,j}$, j=1,…,J are summed up and we obtain $ND_{i,t}(k)$ to get total magnitude of disasters (of type *k*) for country *i* and year *t*. Also the similar intensity measure is established by the International Monetary Fund (2003) and used by Becker and Mauro (2006).

Results for all countries in the sample (without dividing into developing and advanced countries because of problem of multicollinearity) are reported in Table B5 in Appendix B. This model gives the following results: in the

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[1] $\mathrm{ND}_{\mathrm{i,t}}(\mathrm{k}) = \sum_{\mathrm{j=1}}^{\mathrm{J}} \mathrm{intensity}^{\mathrm{k}}_{\mathrm{i,t,j}}$,

where J - total number of k-events (k=1 for drought, k=2 for flood, k=3 for earthquake, k=4 for storm) that took place in county i during year t

$$\mathrm{intensity}^{\mathrm{k}}_{\mathrm{t,i,j}} = \frac{\mathrm{fatalities}^{\mathrm{k}}_{\mathrm{t,i,j}} + 0{,}3 * \mathrm{total\ affected}^{\mathrm{k}}_{\mathrm{t,i,j}}}{\mathrm{population}_{\mathrm{t,i}}} > 0{,}0001, \text{for moderate disasters}$$

$$> 0{,}01 \text{, for severe disasters}$$

presence of natural disaster variable (severe ND), if R&D expenditures increase by 1%, we would expect GDP per capita to increase by approximately 0.226% compared to 0.234% without natural disasters. Coefficients on drought and EDC show negative and significant impact on GDP per capita but flood has positive and significant impact on GDP per capita. Coefficient on R&D from Equation 1 with the presence of severe natural disasters is less than the coefficient of R&D from direct estimation of R&D on GDP per capita. This result shows immediate effect of severe natural disasters (for year when the disaster occurred). Severe disasters cause more damage and economic rehabilitation after them can be seen in longer period (two or three years). Thus, we obtain smaller coefficient on R&D compared to the direct estimation of R&D on GDP.

Two lags for Estimated Damage Costs (EDC) and Natural disasters (ND) variables are included in model 1 following Fomby et al. (2011). Fomby et al. (2011) test the optimal lag structure using Akaike's information criterion (AIC) and Schwarz's Bayesian information criterion (SBC) for the GDP variable and different groups of countries (developing and developed). The authors take the middle between the AIC and SBC statistics and select the lag length 2 as a basic lag structure for natural disasters variables. Since the effects of lagged variables are small and insignificant, we only report the economic response of real GDP per capita and R&D per capita for year when the disaster occurred.

5.2 Diagnostic Tests

We include Estimated Damage Costs (EDC) and Natural disaster variables (drought, earthquake, flood, storm) in the Equation 1. These variables are almost the same and they can be highly correlated. If it is so, we end up with problem of multicollinearity. The greater the multicollinearity, the greater the standard errors. We check natural disasters variables for collinearity by using correlation matrix which is presented in Table B6. Number, which is greater than 0.5 in absolute value can be a signal for existence of high correlation between two variables. From Table B6 we can say that there is no high correlation between any of ND variables.

Several postestimation tests were performed to check robustness of the results. First, we test for heteroscedasticity using Wald test with the null hypothesis of homoscedasticity or constant variance. We reject the null and conclude heteroscedasticity. Second, we test for serial correlation using Wooldridge test for autocorrelation in panel data with the null hypothesis of no serial correlation. Usually serial correlation tests apply to macro panels with long time series (over 20-30 years) but we also apply this test to 11 years panel data. We reject the null and conclude the data have first-order autocorrelation. Serial correlation causes the standard errors of the coefficients to be smaller than they actually are and higher R-squared. Heteroscedasticity makes standard errors to be biased. To overcome these econometric problems and obtain robust standard errors we use "cluster" option in Stata fixed effects regressions. We also estimate Equation 1 with Driscoll-Kraay standard errors (Table B7, Appendix B). This regression gives standard errors which are robust to such disturbances as: heteroscedasticity, autocorrelation and cross-sectional dependence.

We need to test R&D variable for endogeneity using Durbin-Wu-Hausman test with the null hypothesis: R&D expenditures is an exogenous variable. In order to test R&D variable for endogeneity we need to use instruments: Number of Patents per capita and People with tertiary education (% of total). If percent of people with tertiary education is high in the country, more human capital is devoted to research which leads to a higher rate of production and more innovative products. The patent stock variable is a good candidate for knowledge stock which has positive impact on R&D (Ulku, 2004). Results of the first and second stage of IV estimation are presented in Table B8 (Appendix B). We fail to reject the null and conclude that R&D expenditure is exogenous variable and there is no causality between R&D expenditures per capita and GDP per capita.

Sample selection bias can be viewed as a special case of endogeneity bias, arising when the selection process generates endogeneity in the selected sub-sample. The fundamental issue about sample selection bias which must be considered in this paper is why some countries are not included in the sample. We include 38 countries because they have data both on R&D Expenditures and Estimated damage costs. We could have encountered with the subtype of selection bias – sampling bias[1]. Sampling bias may arise due to a non-random sample of countries, causing some countries less likely to be included than others, resulting in biased sample in which countries are not equally balanced or objectively represented. It leads to the inability of the estimated results to be generalized to all countries. In general, errors occurring in the process of gathering the sample cause sampling bias, while errors in any process thereafter cause selection bias. In the paper we divide countries into developed (18 countries) and developing (20 countries) to obtain more reliable results which incorporate effects of natural disasters on different countries in terms of their economic, social or institutional development. Also we have almost equally balanced number of countries in each category (developed or developing). Thus, estimated results can be generalized to all countries. Of course, if the availability of data on R&D and EDC increases, we can increase the sample and obtain more reliable estimates.

[1] Wikipedia. The free Encyclopedia: http://en.wikipedia.org/wiki/Selection_bias

Chapter 6

CONCLUSIONS

The purpose of this paper was to test the working hypothesis whether natural disasters provide opportunities to adopt new technologies and lead to increasing GDP per capita through increase in R&D expenditures. Increase in R&D expenditures leads to fast economic growth due to boom in construction and modern infrastructure and technology. That is why R&D expenditures are interpreted as a pathway, through which the effect of natural disasters on economic growth is examined.

According to obtained results, in the presence of natural disasters, R&D expenditures increase which leads to faster economic growth. Results also show that the effect of natural disaster is bigger for developing countries. They invest more in new technology after old factories and houses were destroyed and we obtained higher coefficients on R&D.

Not all natural disasters are the same in terms of the sign of the growth response they induce, and, some can entail benefits regarding economic growth. Different types of disasters can and do have different effects (e.g. droughts and storms vs. floods).

Overall, the results from the diagnostic tests and robustness check indicate that the features found in the benchmark results are reliable and they may be viewed as an important point for the future research in the field of economics of natural disasters. Further work is needed on the pathways and mechanisms through which natural disasters affect economic growth. For this purpose, both panel and individual country analysis should be used.

WORKS CITED

Albala-Bertrand, Jose-Miguel. 1993. Natural disaster situations and growth: a macroeconomic model for sudden disaster impacts. *World Development*. 21 (September): 1417-1434.

Amin, Samia and Marcus Goldstein. 2008. Data against natural disasters. *World Bank Report 2008*.

Becerra, Oscar, Eduardo Cavallo and I. Noy. 2012. Foreign Aid in the Aftermath of large Natural Disaster. IDB-WP-333.

Becker, Torbjörn and Paulo Mauro. 2006. Output drops and the shocks that matter. IMF-WP-172 (June).

Bogliacino, Francesco and Marco Vivarelli. 2010. The Job Creation effect of R&D expenditures. IZA DP 4728 (January).

Cavallo, Eduardo and Iian Noy. 2010. The Economics of Natural Disasters. IDB-WP-124 (May).

Giannone, Domenico and Michele Lenza. 2010. The Feldstein–Horioka fact. NBER International Seminar on Macroeconomics 2009. *University of Chicago Press: Chicago, IL.*

Chu, Angus C., and Ching-Chong LAI. 2013. Money and the Welfare Cost of Inflation in an R&D Growth Model. *Journal of Money, Credit and Banking,* 45 (February): 233-249.

Godin, Benoit. 2003. The most cherished indicator: Gross Domestic Expenditures on R&D (GERD). Project on the history and sociology of S&T statistics. Working Paper No.22.

Cuaresma, Jesus-Crespo, J. Hlouskova and M. Obersteiner. 2008. Natural disasters as creative destruction? Evidence from developing countries. *Economic Inquiry*, 46 (February): 214-226.

Dollar, David and A. Kraay. 2002. Growth is good for the poor. *Journal of Economic Growth,* 7: 195–225.

Dacy, Douglas and Howard Kunreuther. 1969. The Economics of Natural Disasters: Implications for Federal Policy. *New York, NY: The Free Press.*

Fomby, Thomas, Yuki Ikeda and N.V. Loayza. 2011. The growth aftermath of natural disasters. *Journal of Applied Econometrics*, 26 (June).

Forni, Mario and Lucrezia Reichlin. 1998. Let's get real: a factor analytic approach to business cycle dynamics. *The Review of Economics and Statistics,* 65: 452–473.

Hallegatte, Stephane and Patrice Dumas. 2009. Can Natural Disasters have Positive Consequences? Investigating the Role of Embodied Technical Change. *Ecological Economics,* 68(March): 777-786.

Hayashi, Toshihiko. 2012. Japan's Post-Disaster Economic Reconstruction: From Kobe to Tohoku. *Asian Economic Journal,* 26(March): 189-210.

Im, Kyuong, Mohammad Hashem Pesaran, and Y. Shin. 2003. Testing for unit roots in heterogeneous panels. *Journal of Econometrics,* 115 (January): 53–74.

International Monetary Fund. 2003. Fund assistance for countries facing exogenous shocks. *Policy Development and Review Department, IMF.*

Jaramillo, Christian. 2007. Natural disasters and growth: evidence using a wide panel of countries. Documento CEDE 2007-14.

Kawai, Masahiro and Peter J. Morgan. 2012. Japan's Post-Triple-Disaster. Growth Strategy. Asian Development Bank Institute (ADBI).WP-376 (August).

Kousky, Carolyn. 2012. Informing Climate Adaptation: A review of the Economic Costs of Natural Disasters, their Determinants, Risk Reduction Options. Resources For the Future. RFF DP 12-28 (July).

Levin, Andrew, Chien-Fu Lin and James Chu Chia-Shang. 2002. Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, 108(January): 1–24.

Levine, Ross, Norman Loayza and T. Beck. 2000. Financial intermediation and growth: causality and causes. *Journal of Monetary Economics,* 46(January): 31–77.

Mankiw, Gregory N., David Romer and David N.Weil. 1992. A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics*, 7(May): 407-437.

Neumayer, Eric and Fabian Barthel. 2011. Normalizing economic loss from natural disasters. A global analysis. *Global Environmenal Change,* 21: 13-24.

Okuyama, Yasuhide. 2003.Economics of Natural Disasters: A Critical Review. Research Paper, Regional Research Institute, West Virginia University.

Okuyama, Yasuhide., Geoffrey J.D. Hewings and Micael Sonis. 2004. *Measuring Economic Impacts of Disasters: Interregional Input-Output Analysis using Sequential Interindustry Model. Modeling the Spatial and Economic Effects of Disasters*. New York: Springer : 77–101.

Peng, Li. 2007. Study on Relationship between R&D Expenditure and Economic Growth of China. Zhengzhou Institute of Aeronautical Industry Management. Proceedings of the 7th International Conference on Innovation & Management.

Pielke, A. Roger and Cristopher W. Landsea. 1998. Normalized hurricane damages in the United States: 1925-1995. *Weather Forecast*, (September): 621-631.

Skidmore, Mark and Hideki Toya. 2002. Do natural disasters promote long-run growth? *Economic Inquiry*. 40 (April): 664-687.

Thomas, Deboreh S.K. 2001. *Data, Data Everywhere. But Can We Really Use Them? In American Hazardscapes: The Regionalization of Hazards and Disasters*. Washington, DC, Joseph Henry Press: 61–76.

Ulku, Hulya. 2004. R&D, Innovation and Economic Growth. An Empirical Analysis. IMF –WP-85 (September).

APPENDIX A. FIGURES

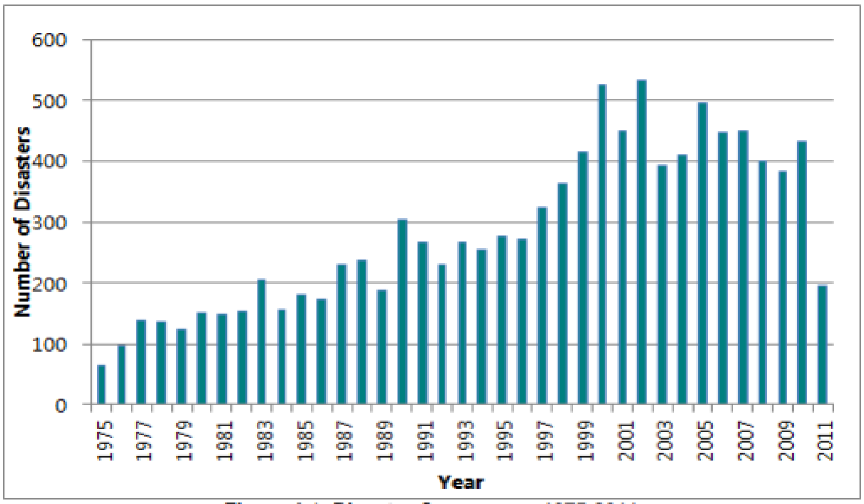

Figure 4-1: Disaster Occurrence, 1975-2011

Figure A1. Disaster Occurrence, 1975-2011
(*Source: ADRC Natural Disasters Data Book 2011)

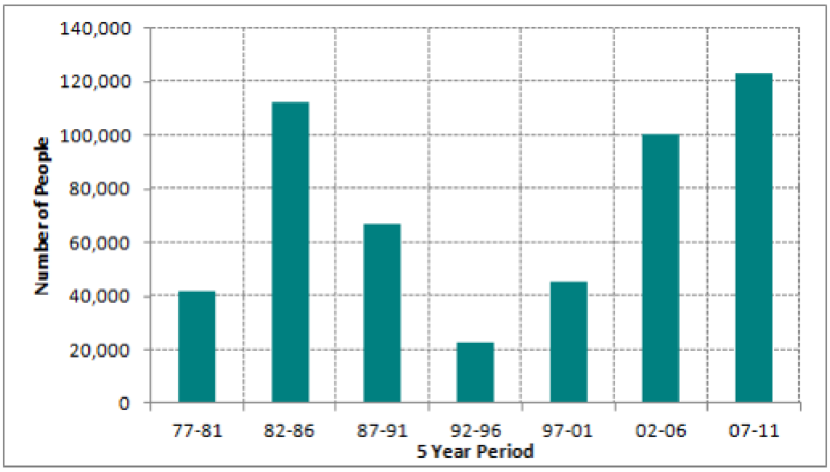

Figure 4-4: Number of People Killed (Average of 5-year period), 1977-2011

Figure A2. Number of People Killed (Average of 5-year period), 1977-2011
(Source: EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels (Belgium))

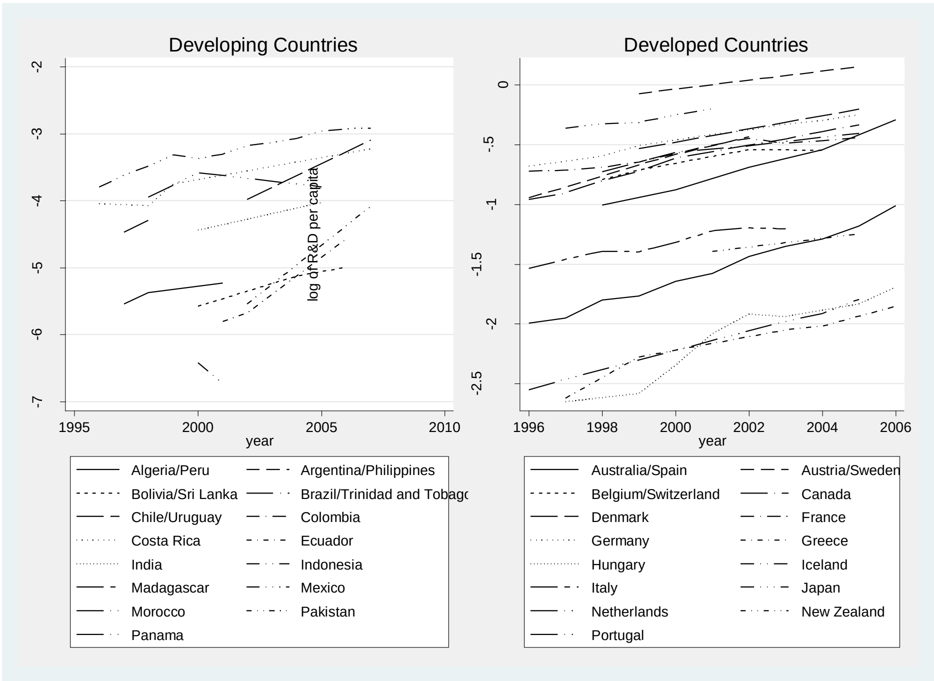

Figure A3. Panel data line plot of log of R&D per capita for Developed and Developing Countries

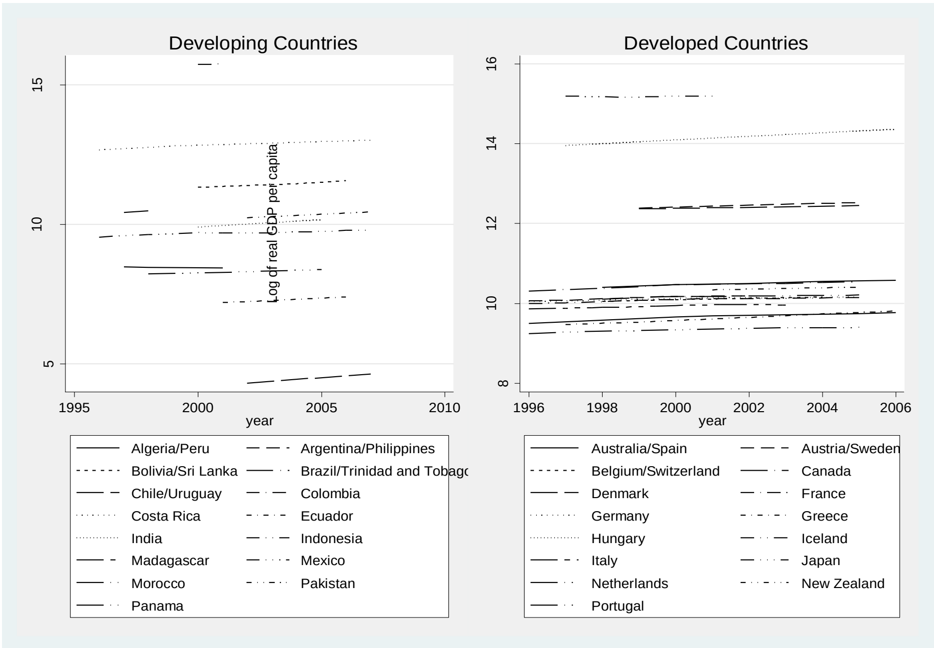

Figure A4. Panel data line plot of log of GDP per capita for Developed and Developing Countries

APPENDIX B. TABLES

Table B1. Descriptive statistics of key variables for Developing Countries

	Observations	Mean	Std.Dev
Log of real GDP per capita	47	10.00	2.37
(Exports+imports)/GDP (in logs)	47	-0.50	0.43
Gross fixed capital formation/GDP (in logs)	47	-1.58	0.19
Domestic credit to private sector/GDP (in logs)	47	-1.29	0.57
Growth rate of general government final consumption expenditure/GDP	47	0.01	0.06
People with Secondary Education (% of total)	47	27.09	12.57
log of R&D per capita	47	-4.22	1.06
Log of EDC	47	11.03	2.91

Table B2. Descriptive statistics of key variables for Developed Countries

Variable	Observations	Mean	Std.Dev.
Log of real GDP per capita	93	10.81	1.70
(Exports+imports)/GDP (in logs)	93	-0.43	0.47
Gross fixed capital formation/GDP (in logs)	93	-1.53	0.13
Domestic credit to private sector/GDP (in logs)	93	-0.09	0.47
Growth rate of general government final consumption expenditure/GDP	93	0.00	0.02
People with Secondary Education (% of total)	93	42.72	14.83
log of R&D per capita	93	-1.04	0.71
Log of EDC	93	12.32	2.32

Table B3. Number of ND, R&D per capita and EDC: impact on GDP per capita. Developing Countries

Impact on log of GDP per capita	(1) R&D,EDC and ND	(2) EDC and ND	(3) R&D
log of R&D per capita	0.232***		0.231***
	[0.041]		[0.042]
Log of EDC	-0.001	0.006	
	[0.002]	[0.005]	
drought	-0.088**	-0.064	
	[0.033]	[0.065]	
earthquake	-0.026	0.010	
	[0.030]	[0.059]	
storm	-0.047**	-0.061	
	[0.021]	[0.056]	
flood	-0.003	-0.011	
	[0.016]	[0.035]	
(Exports+imports)/GDP (in logs)	0.014	-0.137	0.124
	[0.179]	[0.342]	[0.164]
Gross fixed capital formation/GDP (in logs)	0.006	0.492	0.047
	[0.240]	[0.392]	[0.207]
Domestic credit to private sector/GDP (in logs)	0.015	0.030	0.014
	[0.031]	[0.086]	[0.047]
Growth rate of general government final consumption expenditure/GDP	0.321**	-0.318*	0.284
	[0.122]	[0.170]	[0.221]
People with Secondary Education (% of total)	-0.000	-0.002	-0.001
	[0.002]	[0.006]	[0.002]
Constant	11.059***	10.771***	11.155***
	[0.326]	[0.593]	[0.235]
Observations	47	47	47
R^2	0.851	0.430	0.773
Adjusted R^2	0.804	0.272	0.740
Fixed Effects	Yes	Yes	Yes

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B4. Number of ND, R&D per capita and EDC: impact on GDP per capita. Developed Countries

Impact on log of GDP per capita	(1) R&D,EDC and ND	(2) EDC and ND	(3) R&D
log of R&D per capita	0.267***		0.257***
	[0.032]		[0.034]
Log of EDC	-0.001	0.001	
	[0.001]	[0.002]	
earthquake	-0.041	-0.033	
	[0.033]	[0.045]	
storm	-0.005	0.001	
	[0.012]	[0.015]	
flood	0.005	-0.008	
	[0.005]	[0.007]	
(Exports+imports)/GDP (in logs)	0.076	0.307***	0.081*
	[0.049]	[0.058]	[0.044]
Gross fixed capital formation/GDP (in logs)	0.044	0.096	0.049
	[0.078]	[0.102]	[0.077]
Domestic credit to private sector/GDP (in logs)	0.023	0.192**	0.033
	[0.033]	[0.076]	[0.037]
Growth rate of general government final consumption expenditure/GDP	-0.252*	0.170	-0.255*
	[0.133]	[0.176]	[0.138]
People with Secondary Education (% of total)	0.003*	0.005	0.003*
	[0.001]	[0.004]	[0.001]
Constant	11.095***	10.893***	11.085***
	[0.154]	[0.230]	[0.156]
Observations	93	93	93
R^2	0.907	0.745	0.899
Adjusted R^2	0.896	0.718	0.892
Fixed Effects	Yes	Yes	Yes

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Note: drought is omitted because of collinearity

Table B5. Number of severe ND, EDC and R&D per capita: impact on GDP per capita

Impact on log of GDP per capita	(1) R&D,EDC and Severe ND	(2) EDC and Severe ND	(3) R&D
log of R&D per capita	0.226***		0.234***
	[0.023]		[0.026]
Log of EDC	-0.003*	0.001	
	[0.002]	[0.002]	
Severe Drought	-0.173***	-0.184*	
	[0.048]	[0.091]	
Severe Earthquake	-0.007	-0.037	
	[0.027]	[0.032]	
Severe Storm	-0.037	0.006	
	[0.022]	[0.034]	
Severe Flood	0.216***	0.515***	
	[0.072]	[0.113]	
(Exports+imports)/GDP (in logs)	0.044	0.153	0.123**
	[0.048]	[0.111]	[0.049]
Gross fixed capital formation/GDP (in logs)	-0.034	0.029	0.070
	[0.085]	[0.129]	[0.080]
Domestic credit to private sector/GDP (in logs)	0.069*	0.200***	0.038
	[0.034]	[0.061]	[0.029]
Growth rate of general government final consumption expenditure/GDP	0.068	-0.359**	0.171
	[0.150]	[0.167]	[0.190]
People with Secondary Education (% of total)	0.002*	0.005*	0.000
	[0.001]	[0.002]	[0.001]
Constant	10.965***	10.561***	11.199***
	[0.168]	[0.250]	[0.141]
Observations	140	140	140
R^2	0.867	0.599	0.835
Adjusted R^2	0.856	0.568	0.828
Fixed Effects	Yes	Yes	Yes

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B6. Correlation between natural disaster variables

	Log of EDC	drought	earthquake	storm	flood
Log of EDC	1.0000				
drought	0.0770	1.0000			
earthquake	-0.0882	-0.0372	1.0000		
storm	-0.0424	-0.0580	-0.0985	1.0000	
flood	0.0680	0.3684	0.0137	0.1080	1.0000
N=140					

Table B7. FE Regression with Driscoll-Kraay standard errors

Impact on log of GDP per capita	(1) R&D,EDC and ND
log of R&D per capita	0.240***
	[0.010]
Log of EDC	-0.003*
	[0.001]
drought	-0.091***
	[0.023]
earthquake	-0.015
	[0.016]
storm	-0.026**
	[0.011]
flood	0.001
	[0.009]
(Exports+imports)/GDP (in logs)	0.110***
	[0.021]
Gross fixed capital formation/GDP (in logs)	0.025
	[0.057]
Domestic credit to private sector/GDP (in logs)	0.036***
	[0.007]
Growth rate of general government final consumption expenditure/GDP	0.191
	[0.126]
People with Secondary Education (% of total)	0.002**
	[0.001]
Constant	11.120***
	[0.098]
Observations	140
Fixed Effects	Yes

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B8. Results of IV estimation

	(1) First Stage	(2) Second Stage
Number of Patents (in logs)	0.679***	
	[0.129]	
Labor force with tertiary education (% of total)	0.020***	
	[0.006]	
log of R&D per capita		0.278***
		[0.027]
(Exports+imports)/GDP (in logs)	0.928***	0.061
	[0.236]	[0.047]
Gross fixed capital formation/GDP (in logs)	0.351	0.060
	[0.280]	[0.051]
Domestic credit to private sector/GDP (in logs)	0.188**	0.020
	[0.088]	[0.018]
Growth rate of general government final consumption expenditure/GDP	-1.180*	0.264**
	[0.597]	[0.112]
People with Secondary Education (% of total)	0.004	0.001
	[0.008]	[0.001]
Log of EDC	0.014*	-0.005***
	[0.008]	[0.002]
Constant	-6.537***	
	[1.174]	
Observations	112	112
R^2	0.628	0.854
Adjusted R^2	0.440	0.801
Hausman test (p-value)		0.1348

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$