Estimation of Disasters' Economic Impact in 1990-2007:

Global Perspectives

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ABSTRACT

This paper aims to estimate the global and regional impacts of major disasters occurred during 1990 and 2007 using a Computable General Equilibrium (CGE) model (GTAP). 171 major disasters are selected in terms of the size of economic damages, based on the data available from EM-DAT and NatCat databases. The losses and total impacts including higher-order effects of these disasters are estimated using are reproduced using the GTAP-CGE model for concurrent events for consecutive years. Our findings emphasize that economic burden of natural disasters is not confined to the region where the disaster physically occurs, and lead to new global balances in short to medium term, through trade linkages, price and wage effects. Thus, considering natural disasters as separate events, not accounting for global linkages may lead to an underestimation of natural disasters' impact on the world economy.

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The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the view of the World Bank, its Executive Directors, or the countries they represent.

1. Introduction

Natural disasters impact the economy; the current paper simulates the economic impact of major disasters occurred between 1990 and 2007 within a world-wide analytical framework.

This analytical exercise complements the findings of the background paper by Okuyama and Sahin (2009) for the Unites Nations-World Bank Joint Assessment on Economics of Disaster Risk Reduction (2010)[2]. The originality of the paper relies on the fact that, for the first time, a global approach has been used to assess the economic impact of major disasters via a CGE model for the past 17 years.

2. Major Natural Disasters in the World

According to the United Nations' International Strategy for Disaster Reduction (UNISDR), the frequency of disasters caused by natural hazard has been increasing.[3] On average, 78 disasters per year used to occur during the 1970s, this number grew to 351 per year during the 2000s (Figure 1).

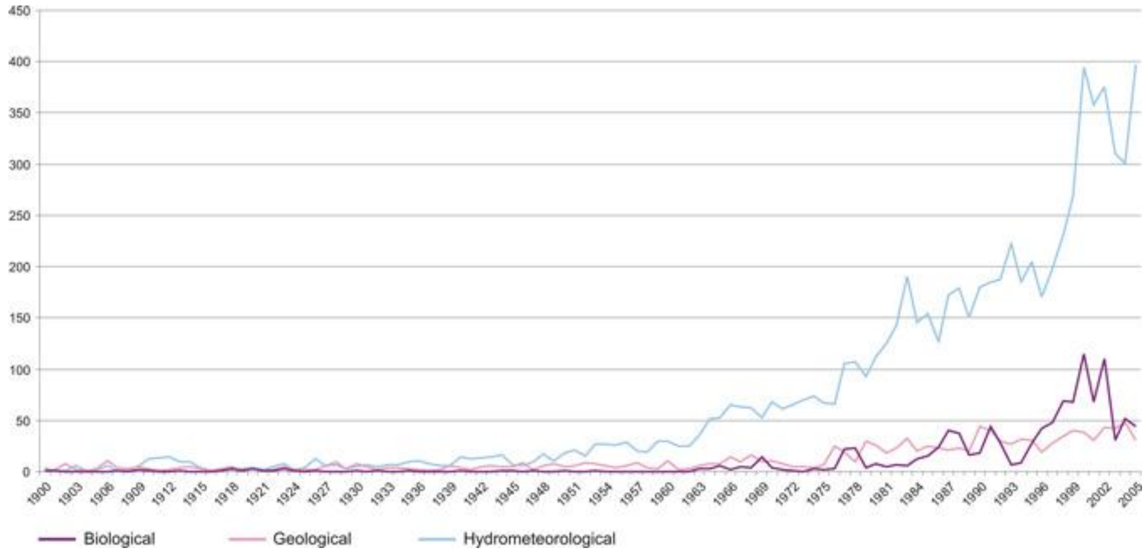

Figure 1. Number of Disasters Registered in EMDAT[4]

[2] Natural Hazards, Un-natural Disasters, The Economics of Effective Prevention (2010), The World Bank and the United Nations, The World Bank, Washington D.C.

[3] http://www.unisdr.org/disaster-statistics/occurrence-trends-century.htm

[4] http://www.unisdr.org/disaster-statistics/occurrence-trends-century.htm; Biological disasters include epidemics and insect infestations.

Economic damages caused by disasters in the world have been also increasing. While more than 60% of the total damages caused by disasters occurred in high-income countries, the estimated damages of disasters as a share of GDP were significantly greater in less developed and small-size countries (UN, 2008).

While some developing countries, like China and Indonesia, are included in the top 50 cases, most of the largest damages occurred in developed countries with relatively small GDP share. The most devastating disasters (in monetary terms), occurred in China, Turkey, Japan and United States are displayed in Table 1. These events explain ¾ of the economic losses reported for the analyzed period, and are well-documented.

Table 1 Most damaging disaster events between 1990 and 2007

Year	Country	Location	Disaster Type	Losses (2005 US$, million)
1996	China	Anhui, Guizhou, Hebei	Flood	10,120
1994	China	Xuwen, Leizhou, Yangjiang	Drought	10,440
1999	Turkey	Izmit, Kocaeli, Yalova	Earthquake	17,059
1998	China	Hubei, Hunan, Sichuan	Flood	25,041
1995	Japan	Kobe, Osaka and Kyoto	Earthquake	78,029
2005	United States	Mobile, Bayou La Batre	Storm	125,000
		Source: Munich Re	Total	265,688

These events are part of our disaster simulation list (Appendix 1).

3. Framework and terminology

Natural hazards occur around the world with a wide range of intensities. Economic damage, or loss data of disasters are collected by various institutions. However no standardized definitions or frameworks of economic damage and loss are set so far, except the use of ECLAC methodology (UN ECLAC, 2003) for recent disasters. It is therefore difficult to collect the consistent measurement of economic damage and loss data for past disasters. Few sources offer the economic damage or loss data of past disasters such as the EM-DAT database by Centre for Research on the Epidemiology of Disasters (CRED) of Université Catholique de Louvain, NatCat database by Munich Re, and Sigma data base by Swiss Re.[5] In this study, economic damage data are gathered from EM-DAT and NatCat databases.

This paper adopts ECLAC terminology described in Table 2, to combine the data available from different sources. Hence economic losses refer to indirect disaster effects (as reported by MunichRe). Higher order effects correspond to system-wide impacts of natural disasters, and they are reproduced using the GTAP-CGE model for each disaster event.

Table 2

ECLAC terminology	
Damages	Direct Effect : Impact on physical capital stock
Losses	Indirect Effect due to - Business interruption, - Destruction of the means of production, - Lack of inputs, - Increased transport cost, etc…
Higher-Order Effects	System-wide impact caused by the losses through relationships between economic agents

Source: ECLAC (2003)

The disaster cases are selected from the ones occurred during 1990 and 2007. As mentioned above, there is no standard definition of economic impact; furthermore, economic damage, loss, and impact of disasters are used interchangeably in various documents, including official ones. In fact, EM-DAT uses 'estimated damage'[6] while

5 Some useful comparison of these databases can be found in Guha-Sapir and Below (2002).

6 EM-DAT states the definition of estimated damage as: "Several institutions have developed methodologies to quantify these losses in their specific domain. However, there is no standard procedure to determine a global figure for economic impact." (http://www.emdat.be/ExplanatoryNotes/explanotes.html)

NatCat's data is labeled as 'overall losses'. It is then useful to clarify the terminology: *damages* are by economics definition the damages on stocks, which include physical and human capitals; *losses* are business interruptions, such as production and/or consumption, caused by damages and can be considered as first-order losses; *higher-order effects*, which take into account the system-wide impact based on first-order losses through inter-industry relationships; and *total impacts* are the total of flow impacts, adding losses (first-order losses) and higher-order effects.[7] Whereas EM-DAT and NatCat databases used different terms for economic data of disasters, we consider both of them as damages, *i.e.* damages on capital stock.

Then, the disaster cases[8] are combined between two databases, and are screened based on the intensity in order to reduce the number of cases by eliminating smaller cases (as in Okuyama and Sahin 2009). The intensity condition is set as: damages should be greater than or equal to US$ 20 million (current), and either should be greater than 1% of current GDP for high-income countries or 2% of current GDP for low income countries. The number of cases after this screening reaches 171 : 70 storms/hurricanes, 57 floods, 23 earthquakes, 21 droughts (see list in Appendix).

4. The CGE Method

In this exercise, the GTAP[9] global computable general equilibrium model is used as a tool to determine the trade-offs on the international markets following a significant disaster happened between 1990 and 2007.

The choice of a CGE model aims (i) to include more flexibility in economic agents' behaviors, (ii) capturing substitution/complementarity relations across demand for goods and services, and (iii) calculating price changes resulting from changing demand and supply conditions.

7 Further discussion of terminology can be found in a companion paper, "Critical Review of Methodologies on Disaster Impact Estimation."

8 These cases include climatological, geophysical, hydrological, and meteorological disasters in EM-DAT definition.

9 For the model description see Hertel (1997) in https://www.gtap.agecon.purdue.edu/

CGE models allow a comprehensive and robust analysis of disasters' impact since; on the one hand, the specification for flows and stocks draw on the economic theory, and officially published data from national accounts. On the other, macro-economic variables' values in the base year and post-disaster periods make possible a comparative analysis of the economic structure before and after the disasters. Also, CGE models may be used for policy analysis regarding recovery and reconstruction activities.

Lexically; *computable* refers to numerically solvable models as opposed to theoretical ones. *General* signifies an economy-wide approach (based on SAM). *Equilibrium* should be satisfied at multiple levels; between (i) demand and supply of factor of production, commodities, and services, (ii) optimizing agents' demands and their budget constraints (*expenses* equal *revenues* for economic agents), and (iii) macro-economic variables in value terms [GDP = C + G + I + (X-M)]. The model consists of non-linear behavioral equations and accounting links (linear relations describing the break-even points in different markets).

In the current paper, disasters analyzed in the previous section are simulated via shocks implemented on the initial model equilibrium in the benchmark year. The shocks refer to (i) a decrease in the initial endowment of factors of production (land in the case of floods, capital in other types of disasters), (ii) a fall in the sectoral marginal productivity of factors of production (land in the case of droughts, capital in other types of disasters), or (iii) a combination of the two.

Shocks have been implemented into the initial equilibrium of the model to reproduce the economic losses as a percentage of the GDP (Appendix 1). The relative magnitude the shocks which lead to satisfactory simulation results, served as starting points for other events.

Although the disaster shock has been implemented only on specific countries, the disaster impact propagates to the Rest of the World. The disaster shock leads to a new equilibrium (short to medium horizon) where disaster-affected economies, and other economies adjust to the new economic conditions. Hence, following the disaster shock this system of simultaneous equations moves from the base-year equilibrium level to a new one.

This new equilibrium implies a shift in the economic structures of the countries; and changes in demand for goods/services, as well as for factors of production. New levels of macro-economic variables, and market-clearing prices for this new equilibrium are determined by the GTAP-CGE model[10].

In this analytical framework, supply of factors of production is fixed and specific to each economy. Recovery/reconstruction activities, and international aid which may flow to a disaster-affected country have not been included in the scope of the current study. In that sense, the model results mimic the new equilibrium between the disaster-affected country and the Rest of the World, following a disaster, in the absence of any external intervention, or additional factors of production. Among other factors, the new equilibrium will be determined by the disaster effect on the terms of trade, on sectoral competitiveness, as well as by the affected economy's weight in the world economy, and the type of goods in which it has a comparative advantage. The overall impact of disasters is expected to be negative in this analytical framework where factors of production are fixed, partly destroyed by disasters, and the possibility of their recovery or regeneration is inexistent.

According to the model outputs (Table 3), the sum natural disasters' impact over the period 1990-2007 reaches 1.44% of the global GDP (in 2007).

Table 3

Disaster Impact (% World GDP, 2007)	
Okuyama and Sahin (2009)	1.15
MunicRe	1.19
Sahin (2011)	1.44

10 The model and the underlying dataset are developed and maintained by the Global Trade Analysis Project (GTAP) network (https://www.gtap.agecon.purdue.edu/). Restricted versions of the model and data are publically available at the GTAP website. "Global Trade Analysis Modeling and Applications", 1997, Ed. Thomas Hertel, NY, USA. provides the basic information about the model and the dataset.

Economic losses produced by the Global CGE model exceed the sum of individual country loss (MunichRe) statistics for each simulation year. The negative impact of a given disaster often propagates to its major partners, even if the latter have not been hit by any disasters in this particular year. This rippling effect explains why the CGE model simulations are higher than the losses reported by insurance statistics --MunichRe or those calculated in Okuyama, Sahin (2009). In the latter, the global impact exclusively consisted of the sum of the individual countries' losses.

The outputs from the three methods look alike in cases where world imports from the disaster affected economy can be perfectly substituted by those from other countries (at equal price and quality). In other cases --where the disaster affected country is a net supplier (exporter) of a particular intermediate or final consumption good-- natural disasters lead to second best solutions. In fact, these price differences for traded commodities pre-exist in the GTAP dataset as differences in transport costs, tariffs, or other protectionist measures, etc.

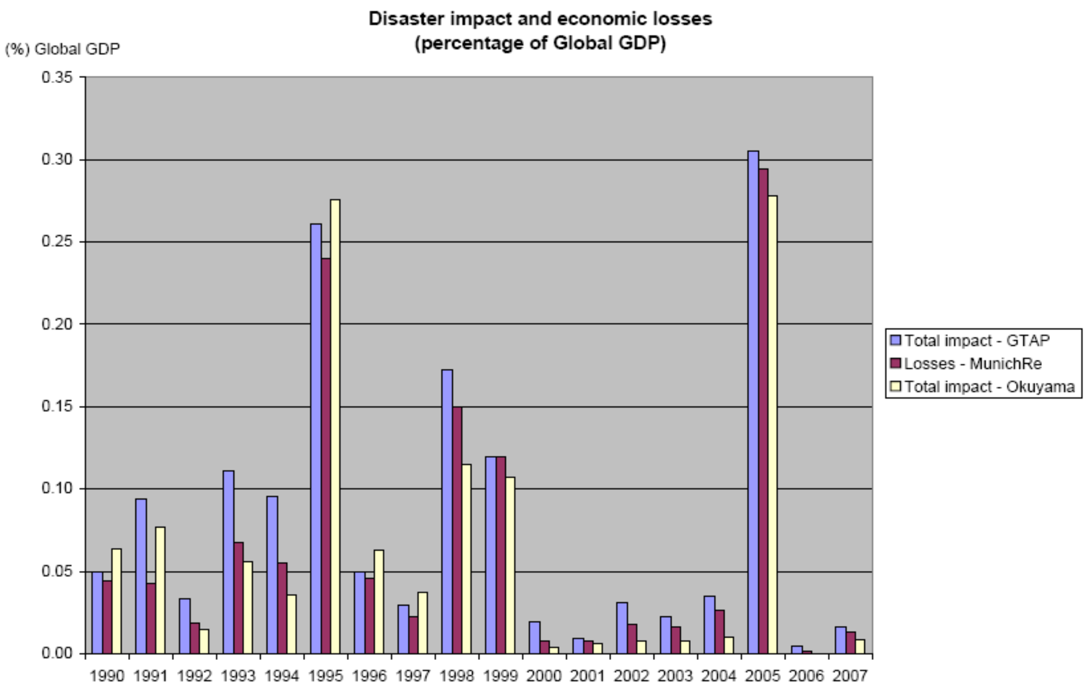

Figure 2

The historical trends of economic impacts show a gradual increase of all the three economic impacts is observed until year 2000, with an exception of 1995 including the

Hanshin-Awaji (Kobe) Earthquake in Japan. Between 2001 and 2004, a lull of economic impacts is observed; and then, year 2005 becomes another exception with Hurricane Katrina in the U.S.

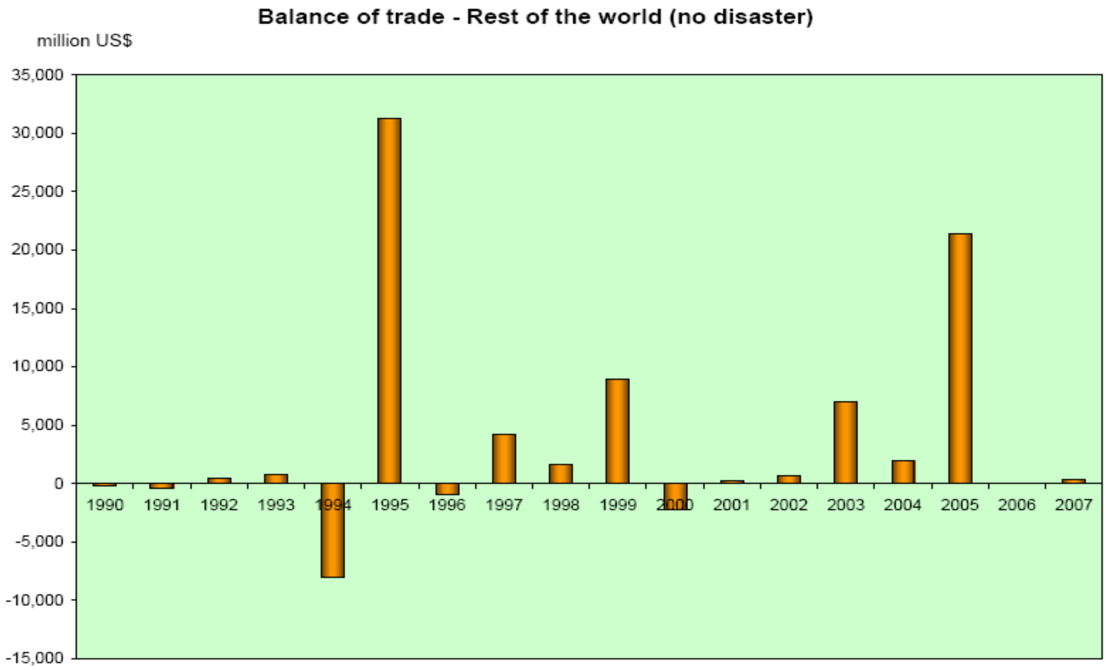

Figure 3

Many economists/ practitioners argue that disasters' negative impact at the international level is inexistent or undetectable. Within a CGE framework, trade effects result in a zero sum game at the global level. Simulations illustrate that, for each year, trade surpluses in countries --which have not been hit by any disaster-- counterbalanced the trade deficits occurring in disaster hit countries (Figure 3).

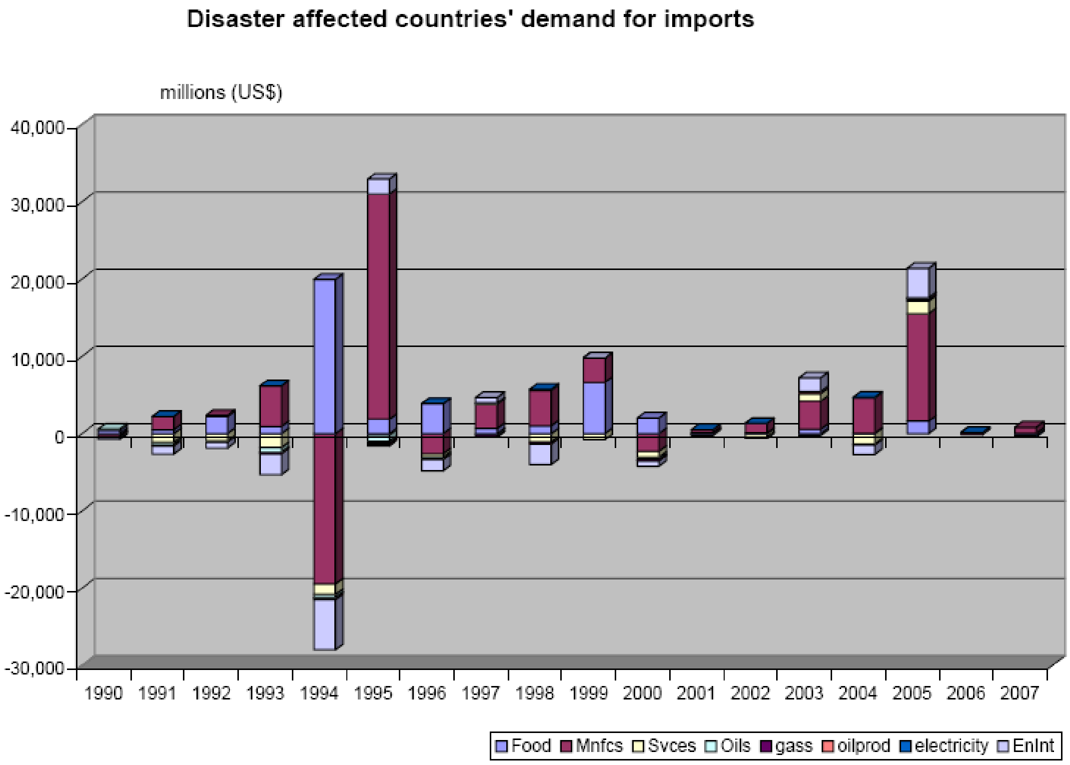

Figure 4

1994 stands as an exception where floods and droughts have been the major reported events (Figure 4). In this particular year, disaster affected countries' demand for agricultural goods and food products increased significantly. For the rest of the simulations, imports from non-affected countries mainly consisted of manufactured goods, and energy --which illustrate the need for intermediate goods to be used in reconstruction activities. Consequently, among the simulation results, when disasters happen in *net exporter countries* of intermediate goods (i.e. Japan), the impact on the global economy seems much more severe than the cases when they occur in *net importers* of intermediate goods. This feature underlined also the cases where disasters hit an oil exporting country (e.g. earthquakes in Iran and Algeria). In these examples, CGE model simulations largely exceeded the losses reported by insurance statistics, and those calculated in the previous section.

5. Synthesis of the preliminary results

Economic losses produced by the Global CGE model exceed the sum of individual country loss (MunichRe) statistics for each simulation year. The negative impact of a given disaster often propagates to its major partners, even if the latter have not been hit by any disasters in this particular year. This rippling effect explains why the CGE model simulations are higher than the losses reported by insurance statistics --MunichRe or those calculated in the previous section. In the latter study, the global impact exclusively consisted of the sum of the individual countries' losses.

We conclude that the economic burden of natural disasters is not confined to the region where the disaster physically occurs; in the short to medium term, natural disasters lead to new global balances through trade linkages and price effects. We may be underestimating natural disasters' impact by considering them as separate events and not taking into account the global linkages.

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Appendix

1. List of simulated disaster events

Year	Country	Disaster Type	Est. Damage (US$ Million)	Current GDP (US$ million)
2003	Croatia	Drought	330	29,593
2003	Bosnia and Herzegovina	Drought	140	8,370
2000	Romania	Drought	500	37,053
2000	Georgia	Drought	200	3,057
2000	Bosnia and Herzegovina	Drought	158	5,338
2000	Azerbaijan	Drought	100	5,273
2000	Armenia	Drought	100	1,912
2000	Tajikistan	Drought	57	980
1999	Iran, Islamic Rep.	Drought	3,300	104,656
1999	Morocco	Drought	900	39,756
1999	Uruguay	Drought	250	21,189
1999	Mauritius	Drought	175	4,258
1998	El Salvador	Drought	170	12,008
1997	Vietnam	Drought	407	26,844
1997	Guyana	Drought	29	749
1994	China	Drought	13,755	559,226
1994	Cambodia	Drought	100	2,791
1992	Hungary	Drought	384	37,254
1990	Yugoslavia	Drought	1,000	4,828
1990	Mozambique	Drought	50	2,463
1990	Namibia	Drought	50	2,350
2007	Peru	Earthquake	2,000	109,088
2005	Pakistan	Earthquake	5,200	109,502
2004	Indonesia	Earthquake	4,452	256,837
2004	Sri Lanka	Earthquake	1,317	20,663
2004	Maldives	Earthquake	470	776
2004	Seychelles	Earthquake	30	700
2003	Algeria	Earthquake	5,000	68,019
2002	Georgia	Earthquake	350	3,396
2001	El Salvador	Earthquake	1,500	13,813
2001	El Salvador	Earthquake	349	13,813
1999	Turkey	Earthquake	20,000	248,961
1999	Greece	Earthquake	4,200	154,400
1999	Colombia	Earthquake	1,857	86,283
1998	Azores	Earthquake	72	4,446
1997	Armenia	Earthquake	33	1,639
1995	Japan	Earthquake	100,000	5,247,609
1994	Uganda	Earthquake	70	3,990

1992	Egypt, Arab Rep.	Earthquake	1,200	41,855
1992	Kyrgyzstan	Earthquake	130	2,317
1992	Kyrgyzstan	Earthquake	31	2,317
1992	Nicaragua	Earthquake	25	1,793
1991	Costa Rica	Earthquake	100	7,163
1990	Iran, Islamic Rep.	Earthquake	8,000	116,035
2007	Bolivia	Flood	500	13,120
2007	Mozambique	Flood	100	7,752
2006	Guyana	Flood	169	908
2005	Guyana	Flood	465	826
2005	Tajikistan	Flood	50	2,311
2004	Bangladesh	Flood	2,200	56,561
2003	Zimbabwe	Flood	200	7,397
2003	Sudan	Flood	184	17,780
2003	Madagascar	Flood	150	5,474
2003	Tajikistan	Flood	20	1,554
2002	Austria	Flood	2,400	207,831
2002	Czech Republic	Flood	2,400	75,276
2002	Russia	Flood	500	45,825
2002	Bolivia	Flood	100	7,905
2002	Honduras	Flood	100	7,776
2001	Bolivia	Flood	121	8,142
2000	Bangladesh	Flood	500	47,097
2000	Mozambique	Flood	419	4,249
2000	Cambodia	Flood	160	3,654
1999	Venezuela, RB	Flood	3,160	97,974
1999	Papua New Guinea	Flood	43	3,477
1998	China	Flood	30,000	1,019,459
1998	Bangladesh	Flood	4,300	44,092
1998	Tajikistan	Flood	66	1,320
1997	Poland	Flood	3,500	157,082
1997	Czech Republic	Flood	1,850	57,135
1997	Ecuador	Flood	271	23,647
1997	Moldova	Flood	50	1,930
1996	China	Flood	12,600	856,090
1996	Costa Rica	Flood	250	11,843
1995	Macedonia, FYR	Flood	245	4,449
1994	Moldova	Flood	300	1,702
1994	Vietnam	Flood	206	16,286
1993	India	Flood	7,000	276,037

1993	China	Flood	6,061	440,502
1993	Thailand	Flood	1,261	125,009
1993	Iran, Islamic Rep.	Flood	1,000	60,088
1993	Nepal	Flood	200	3,660
1993	Turkmenistan	Flood	100	3,179
1993	Honduras	Flood	58	3,482
1993	Honduras	Flood	57	3,482
1992	Pakistan	Flood	1,000	48,635
1992	Tajikistan	Flood	300	1,909
1992	Sri Lanka	Flood	250	9,703
1992	Bolivia	Flood	100	5,644
1992	Lao PDR	Flood	22	1,128
1991	China	Flood	7,500	376,617
1991	Cambodia	Flood	150	1,633
1991	Malawi	Flood	24	2,204
1990	Tunisia	Flood	243	12,291
1990	Honduras	Flood	100	3,049
2003	Tajikistan	Mass movement \	41	1,554
1994	Kyrgyzstan	Mass movement \	36	1,681
1993	Ecuador	Mass movement \	500	15,063
1993	Tajikistan	Mass movement \	149	1,647
1992	Bolivia	Mass movement \	400	5,644
1992	Tajikistan	Mass movement \	24	1,909
2005	United States	Storm	125,000	12,397,900
2007	Bangladesh	Storm	2,300	67,694
2007	Pakistan	Storm	1,620	143,597
2007	Jamaica	Storm	300	10,739
2007	Madagascar	Storm	240	7,326
2007	St. Lucia	Storm	40	958
2007	Dominica	Storm	20	328
2007	Belize	Storm	15	1,274
2006	Vietnam	Storm	624	60,999
2005	Guatemala	Storm	988	27,285
2005	El Salvador	Storm	356	17,070
2005	Latvia	Storm	325	16,042
2005	Honduras	Storm	100	9,671
2005	Haiti	Storm	50	4,312
2004	Grenada	Storm	889	434
2004	Jamaica	Storm	595	8,886
2004	Jamaica	Storm	300	8,886

2004	Dominican Republic	Storm	296	18,452
2004	Madagascar	Storm	250	4,364
2004	Haiti	Storm	50	3,841
2004	St. Vincent and the Grena	Storm	5	415
2003	Fiji	Storm	30	2,309
2002	Mauritius	Storm	50	4,549
2002	St. Vincent and the Grena	Storm	11	364
2001	Bahamas, The	Storm	300	5,131
2001	Belize	Storm	250	871
2001	Tonga	Storm	51	130
2000	Belize	Storm	277	832
2000	Mongolia	Storm	80	1,089
2000	Moldova	Storm	32	1,288
1999	Denmark	Storm	2,605	173,944
1999	Bahamas, The	Storm	450	4,575
1999	St. Kitts and Nevis	Storm	41	305
1999	Grenada	Storm	6	380
1998	Honduras	Storm	3,794	5,202
1998	Dominican Republic	Storm	1,982	15,850
1998	Puerto Rico	Storm	1,750	54,086
1998	Nicaragua	Storm	988	3,572
1998	Guatemala	Storm	748	19,394
1998	St. Kitts and Nevis	Storm	400	287
1998	El Salvador	Storm	388	12,008
1998	Haiti	Storm	180	3,779
1998	Antigua and Barbuda	Storm	100	620
1997	Vietnam	Storm	470	26,844
1997	Madagascar	Storm	50	3,546
1997	Fiji	Storm	27	2,094
1996	Puerto Rico	Storm	500	45,341
1996	Vietnam	Storm	362	24,657
1996	Costa Rica	Storm	200	11,843
1996	Azores	Storm	66	3,177
1995	Bangladesh	Storm	800	37,940
1995	Antigua and Barbuda	Storm	400	494
1995	St. Kitts and Nevis	Storm	197	231
1995	Dominica	Storm	175	224
1995	Dominica	Storm	20	224
1994	Mauritius	Storm	135	3,373
1994	Haiti	Storm	50	2,379

1993	Lao PDR	Storm	302	1,328
1993	Fiji	Storm	100	1,635
1993	Mongolia	Storm	10	658
1993	Vanuatu	Storm	6	188
1993	Eritrea	Storm	5	468
1992	Fiji	Storm	261	1,532
1992	Bahamas, The	Storm	250	3,178
1992	Lebanon	Storm	155	5,546
1991	Bangladesh	Storm	1,780	30,957
1991	Samoa	Storm	278	112
1991	Maldives	Storm	30	244
1990	Samoa	Storm	200	112
1990	Tonga	Storm	3	114
1994	Papua New Guinea	Volcano	110	5,503
1990	Mongolia	Wildfire	110	2,093

2. GTAP sectors/ commodities:

57 sectors are gathered into eight categories to facilitate the implementation of the disaster shock in the simulations, and the reading of the model outputs.

Agriculture : Primary Agriculture, Forestry and Fishing
(Paddy rice; wheat; cereal grains nec; vegetables, fruit, nuts; oil seeds; sugar cane, sugar beet; plant-based fibers; crops nec; bovine cattle, sheep and goats; animal products nec; raw milk; wool, silk-worm cocoons; forestry; fishing)

Coal : Coal Mining

Oil : Crude oil

Gas : Natural gas extraction, gas; gas manufacture, distribution

Oil_Pcts : Refined oil products, petroleum, coal products

Electricity : Electricity

En_Int_ind : Energy intensive industries, minerals nec; chemical, rubber, plastic prod; mineral products nec; ferrous metals; metals nec.

Oth_ind_ser : Other industries and services
Bovine cattle, sheep and goat ; meat products; vegetable oils and fats; dairy products; processed rice; sugar; food products nec; beverages and tobacco products; textiles; wearing apparel; leather products; wood products; paper products, publishing; metal products; motor vehicles and parts; transport equipment nec; electronic equipment; machinery and equipment nec; manufactures nec; water; construction; trade; transport nec; water transport; air transport; communication; financial services nec; insurance; business services nec; recreational and other service; public administration and defence,

education; ownership of dwellings.