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Comparative Vulnerability to Natural Disasters in the Caribbean

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No. 1/00 "Comparative Vulnerability to Natural Disasters in the Caribbean", Tom Crowards

No. 2/00 "Exchange Rate Crises and Capital Market Imperfections in Small Open Economies", Chris Crowe

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ABSTRACT

Natural disasters can have catastrophic impacts. These may be economic, social and environmental. Damage to infrastructure can severely impede economic activity. Social impacts can include loss of life, injury, ill health, homelessness and disruption of communities. Environmental damage can range from the felling of trees to the reshaping of entire landscapes. It is claimed, for instance, that "*from 1960 to 1989, hurricanes in the Greater Caribbean Basin resulted in the deaths of 28,000 people, disrupted the lives of 6 million people and destroyed property worth U.S. $16 billion*," (Pulwarty and Riebsame, 1997, p.194; attributed to OAS, 1991).

Measuring the comparative vulnerability of countries to natural disasters can serve to draw attention to the issue, identify sectors of the economy or society that are particularly at risk, and assist in planning to mitigate the effects of future events. In addition, a wider international comparison may serve to highlight the particular vulnerability to natural disasters of small island states such as those of the Caribbean.

A convincing comparison between countries will need to quantify vulnerability to disasters. This will inevitably be based, at least in part, on the historical incidence of events and their magnitude. A number of alternative means of quantifying economic vulnerability to natural disasters are considered. The first is based simply on the number of events experienced by each country over a given time period, but this approach ignores the critical issue of the impact associated with each event.

Economic impacts of natural disasters can be measured directly by assessing changes in economic variables associated with the occurrence of natural disasters. A methodology that measures impact in terms of changes in economic variables before and after disasters is applied to a set of 21 of the most severe storms and hurricanes experienced in the Caribbean between 1974 and 1996. General patterns can be identified in some variables, such as gross domestic product (GDP), exports, imports and tourist arrivals. However, such patterns mask huge variations in the behaviour of variables between different disaster episodes. The large number of anomalous results suggests that this approach is unsuitable for comparing relative vulnerability of countries to natural disasters.

Overall economic impacts can also be estimated by using volatility of agricultural output as a proxy measure. This approach is based on the fact that the agricultural sector is particularly sensitive to adverse natural phenomena. Once again, however, this approach appears unsuitable for assessing comparative vulnerability to natural disasters.

The most commonly recorded impacts of natural disasters are the number of deaths, the number of injuries, the number of people made homeless, the total number of people 'affected' and the monetary cost of damage caused. The value of these measures for cross-country comparison of impacts and hence vulnerability is considered. A key concern with each of the measures is the quality of the data.

A compromise measure of comparative vulnerability is derived by combining information on the number of deaths from, and number of people affected by, natural disasters between 1950 and 1998.

The study highlights the inadequacy of historical data alone for assessing vulnerability to possible future disasters. Expert assessment of future episodes is required based on aspects such as historical incidence and impact of events, mitigation measures in place, concentration of development, economic structure, and climatic and geophysical variables.

ABBREVIATIONS

AG	-	Anguilla
AN	-	Antigua and Barbuda
BA	-	The Bahamas
BD	-	Barbados
BVI	-	British Virgin Islands
BZ	-	Belize
CI	-	Cayman Islands
CRED	-	Centre for Research on the Epidemiology of Disasters
DO	-	Dominica
EM-DAT	-	CRED International Database on Disasters
EU	-	European Union
GDP	-	Gross Domestic Product
GR	-	Grenada
GY	-	Guyana
JA	-	Jamaica
mn	-	million
MO	-	Montserrat
NFA	-	Net Foreign Assets
SIDS	-	Small Island Developing States
SK	-	St. Kitts and Nevis
SL	-	St. Lucia
SU	-	Suriname
SV	-	St. Vincent and the Grenadines
TCI	-	Turks and Caicos Islands
TT	-	Trinidad and Tobago
UNCDP	-	United Nations Committee on Development Policy
UNDRO	-	United Nations Disaster Relief Organisation

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COMPARATIVE VULNERABILITY TO NATURAL DISASTERS IN THE CARIBBEAN

INTRODUCTION

Natural disasters can have catastrophic impacts. These may be economic, social and environmental. Damage to infrastructure can severely impede economic activity; social impacts can include loss of life, injury, ill health, homelessness and disruption of communities; and environmental damage can range from the felling of trees to the reshaping of entire landscapes. It is claimed, for instance, that "*from 1960 to 1989, hurricanes in the Greater Caribbean Basin resulted in the deaths of 28,000 people, disrupted the lives of 6 million people and destroyed property worth U.S. $16 billion*," (Pulwarty and Riebsame, 1997, p.194; attributed to OAS, 1991).

Measuring the comparative vulnerability of countries to natural disasters can serve to draw attention to the issue, identify sectors of the economy or society that are particularly at risk, and inform planning to mitigate the effects of future events. Interest in comparing countries' vulnerability to natural disasters has been fuelled in recent years by the call by small island developing states (SIDS) for their relative vulnerability to be acknowledged by international agencies and donor institutions. SIDS are often located in areas prone to events such as hurricanes (or typhoons) and volcanic activity. The inevitable concentration of their economic activity in the coastal zone makes them particularly prone to storm surges and tsunamis, and when a natural catastrophe occurs, the impact for such small states is invariably of national proportions. This point is emphasised in the following quote in a report by the United Nations Conference on Trade and Development:

> *"Island developing economies are often particularly exposed to natural hazards for fundamental reasons of geography. Given the small size of individual islands and of island developing countries generally, the often overwhelming proportional impact of disasters in these countries justifies special concern by the international community,"* UNCTAD (1983, p.33).

A convincing comparison between countries will need to quantify vulnerability to disasters. This will inevitably be based, at least in part, on the historical incidence of events and their magnitude.

A number of measures can been employed to estimate comparative vulnerability to natural disasters based on historical information. The following measures are analysed in the present study and calculated, with an adjustment for country size where appropriate, for a sample of 18 Caribbean countries:

(a) number of historical episodes over approximately 100 years;

(b) changes in macroeconomic variables before and after specified events;

(c) volatility of agricultural production over a period of time (of around 20 years for most Caribbean countries);

(d) damage costs (of a limited number of disaster events);

(e) number of persons affected (by identified events over the past 30 to 50 years); and

(f) number of deaths (attributed to identified events over the past 30 to 50 years).

The validity of using each of these measures for comparative assessment of vulnerability to natural disasters is considered in turn, followed by the results of applying each method to the Caribbean sample. The importance of applying expert analysis to measures of natural disaster vulnerability is also considered.

ALTERNATIVE MEASURES FOR ASSESSING COUNTRIES' VULNERABILITY TO NATURAL DISASTERS

The Number of Natural Disaster Events[1/]

The data available on the number of natural disaster events are more reliable, consistent and span a far greater time period than for any of the other measures. This is a major advantage. However, the inability to differentiate between different types of event and their severity renders this measure of limited use for detailed analysis.

Another drawback of this measure is that it ignores social factors relating to vulnerability or the degree of mitigation. It is generally recognised that factors such as poverty and environmental degradation may increase local vulnerability (see, for instance, UNDRO, 1986; Kreimer and Munasinghe, 1991). As noted in CRED (1997, p.7), "*natural disasters concern the interaction of natural hazards and socio-economic systems rather than natural hazards per se*."

The number of natural disaster events historically experienced in a country could be considered as a measure of inherent vulnerability in the absence of mitigation, but does not accurately portray current vulnerability to natural disasters. Considering the number of events in relation to population size (or land area) serves to indicate the proportional impact. However, some events can affect a considerable proportion of even a larger country, so that adjustment for population size might significantly understate the relative impact for large countries.

Macroeconomic Impacts

Natural disasters can have a significant impact on the broad economy, especially in small states where a single event can affect a large proportion of the country. In a study of the effects of hurricane Gilbert on Jamaica, Brown (1994) emphasises the impact on inflation, the trade balance and tourism. An approach to providing comparative quantitative estimates of effects on such variables was applied to 108 developing countries by Pantin (1997). The difference in seven possible economic indicators between the three years prior to an event and the three years following the event is interpreted as a measure of impact. The variables selected are the rates of change in: GDP, merchandise exports, merchandise imports, exchange rate, rate of inflation,

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[1/] Definitions of a disaster event vary. The Office of U.S. Foreign Disaster Assistance includes the following: a) disasters warranting a U.S. government emergency response; b) earthquakes and volcanoes with at least six persons killed, or at least 25 total killed and injured, or at least 1,000 homeless or affected, or at least US$1mn damage; c) weather disasters, excluding drought, with at least 50 killed and injured, or at least 1,000 homeless or affected, or at least US$1mn damage; and d) droughts where "the number of people affected is substantial" (USOFDA, 1993). In terms of the EM-DAT database, "a disaster is a situation or event which overwhelms local capacity, necessitating a request to the national or international level for external assistance" (CRED, year unknown, p.5).

external debt and gross domestic investment. The averages of the rates of change in these variables before and after each event are calculated. The difference before and after each event is averaged across events to form a single difference figure for each country for each variable. These are then further averaged across variables for each country to derive a single index of macroeconomic change.

A number of problems are associated with this approach:

(a) Combining the seven economic indicators (or any combination of these) implies that they are equally weighted in terms of their economic significance.

(b) The economic data series required for such an analysis are available for a restricted historical period only, thereby limiting the time span that can be considered.

(c) The particular methodology employed by Pantin (1997) is, unfortunately, prone to suggest that small states are more vulnerable. This stems from taking the ***average***, over the period, of differences in the rate of change for each economic variable before and after natural disasters. This ignores the fact that larger countries, under the same conditions, are likely to suffer from a greater number of events. Note that, in considering percentage changes in variables, the difference in scale between countries is already accounted for. So that, for instance, a similar event experienced by a larger economy is likely to have a smaller impact on percentage growth in GDP (although a greater absolute economic impact). However, if it experiences more of these relatively smaller impacts, as might be expected, the net result could be similar to the few, but proportionally larger, impacts experienced by a small country. It is the ***cumulative*** impacts over the period that should, therefore, be measured. By assessing the average impact, undue prominence is afforded to the relatively few events experienced by small countries, while the fact that larger countries may experience more, perhaps less devastating, events, is ignored.

(d) The results are sensitive to the time period under consideration, and even more so when the impacts are summed rather than averaged. In addition to the omission of major events that may have occurred before or after the chosen period – which is common to all historical analyses – the extent to which cumulative impacts are captured will necessarily depend upon the time period analysed.

(e) A more fundamental problem is the unlikely assumption that there are no other influences on the macroeconomy during the seven-year period analysed for each disaster. This suggests not only stable external and domestic political and economic conditions, but also that no other natural disasters occur during those seven years.

(f) A further problem arises with averaging annual changes in each variable. The recovery from an initial negative impact can lead to high rates of growth in proceeding years. The average of these negative and positive growth rates will reduce the apparent impact. What is being measured is a combination of negative impact ***and*** subsequent recovery. Or, where there is a delay in the impact, the average will include the initial unaffected rate of growth.

(g) It could happen that the differential timing of impacts within a country dampens the apparent overall effect. For instance, in St. Lucia in 1982, two years after hurricane Andrew hit the island, growth in cruiseship passenger arrivals rebounded from a previous drop of -68% back up to +79%. In the same year, merchandise exports recorded zero growth and GDP growth fell from 4.8% to 2.1%. Direct comparison across sectors in each year, therefore, may be of limited value when each sector can react according to a very different time scale.

(h) It also appears that, by omitting the actual year of the disaster from the analysis, Pantin misses some significant immediate impacts. For instance, the 5% decline in tourist arrivals and 44% decline in merchandise exports in Montserrat in 1989, the year that hurricane Hugo hit. Or the 12% decline in Jamaica's tourist arrivals in 1988, when hurricane Gilbert swept through the island, which was followed by growth rates of between 10% and 20% in the following three years (and it these latter years that will be picked up in Pantin's methodology).

Agricultural Production Volatility

Agriculture is particularly susceptible to extreme climatic events, and the instability of agricultural production has been recommended as a measure of countries' vulnerability to natural disasters by the United Nations Committee for Development Policy (UNCDP) as part of the criteria for eligibility for Least Developed Countries status (UNDESA, 1999). Agricultural production is measured in terms of aggregate volume as estimated for each country by the United Nations Food and Agriculture Organization.

The UNCDP proposes measuring instability of agricultural production as the annual variance from a measure combining its long-term trend and the previous year's production. This approach suffers from the fact that shifts in trend (i.e. continuous increases or decreases in production) can result in a high measure of variance that erroneously suggests a large degree of instability.

More importantly, agricultural instability may be of questionable use in estimating vulnerability to natural disasters. Agricultural production tends to be unstable even in the absence of disasters, due to supply factors such as variations in weather, changes in technology and availability and cost of inputs, whether human, capital, material or environmental. It is also questionable whether impacts on agricultural output will adequately reflect wider economic or social impacts[2/]. This will be influenced by the importance of agriculture to the economy and by structural features of the economy. Some industries, such as financial services, will react very differently to shocks than will agriculture, while some shocks are more specific to agriculture. For instance, pest infestations and combinations of flood and drought can severely impair agricultural performance but will have less of an effect on other sectors. In contrast, some natural disasters causing extensive damage in other areas can have relatively little effect on agriculture, such as earthquakes and sea surges.

The structure of the agricultural sector (including crops, livestock, fishing and forestry) will also affect the applicability of agricultural instability to measuring natural disaster vulnerability.

[2/] The assumption that impacts on agricultural activity reflects broader economic and social shocks may be more reasonable for the world's least developed countries that are the focus of the United Nation's proposed use of this measure.

A further concern is the potential for positive shocks to be registered as vulnerability to natural disasters due to their contribution to the instability of agricultural production. Such shocks might result, for example, from price increases, new market opportunities or improved technology. There are a number of recent examples of such positive agricultural growth in the Caribbean. These include the rise in banana exports during the 1980s in the Windward Islands, and a temporary boom in Guyana's rice exports during the mid 1990s through a 'loophole' in European Union (EU) import restrictions.

Damage Costs

The initial damage caused by a natural disaster does not represent the full range of economic consequences, but it can be taken as a proxy for the overall impact. The primary drawback of this measure is limited data. The quality of data is also an issue, as reporting ability and procedures vary across countries. As the Programme of Disaster Preparedness of the European Community Humanitarian Office notes in its assessment of the Caribbean, "*it is even more difficult to establish the effect of natural disasters on the region's economic activities than it is to gauge their effect on the population*" (DIPECHO, 1999).

The majority of disasters in the recent past do not have estimates of damage costs, and the number of estimates declines further back in time. Those estimates that do exist can be highly subjective. In the Centre for Research on the Epidemiology of Disasters' (CRED) International Database on Disasters (EM-DAT), compiled by CRED (2000), only 26% of worldwide disasters between 1990 and July 1998 have a cost estimate associated with them. This is consistent with the IFRC (1995) finding in its 'World Disasters Report, 1995', when comparing the average estimated damage by natural disasters across regions for 1989-93. It was found that, "*only some 24 percent of those disasters recorded have a financial loss figure associated with them*" (IFRC, 1995, taken from the IFRC internet site).

An additional concern with employing damage costs as a measure of impact is that it will inevitably place a higher value on damage to more costly assets. It will, therefore, understate relative losses endured by the poorer in society, who may have few, if any, valuable assets. Significantly, it is often the poor who are most hard hit by natural disasters (D'Ercole and Pigeon, 1998).

The Extent of Insurance Claims

A particular means of determining damage costs associated with major events is through assessment of insurance claims. However, even if all property was insured and claims accurately reflected the extent of the damage, problems would arise with the use of this measure to assess vulnerability to natural disasters. Social impacts, such as displacement of population, will be only minimally reflected. The value of insured losses will be disproportionately influenced by high value private property but relatively unaffected by losses to the poorer sectors of society. While the value of public goods to society might reasonably be approximated by their financial value, this need not be the case for private assets.

In reality, a great deal of property is not insured. This is certainly the case for the majority of public infrastructure and private property in the Caribbean. The absence of widespread catastrophe insurance renders this measure of little practical value for comparative assessment of vulnerability, regardless of the inadequacies noted above.

Using damage costs to assess vulnerability to natural disasters exemplifies the key problem with the available measures of impact: the lack of data over a long time scale. This is important since a short time scale will understate the likelihood of less frequent but perhaps more powerful events.

Number of Persons Affected by Natural Disasters

The measure of number of persons affected can provide an indication of the extent of disasters and their effect on human activity. It encapsulates measures of the number injured and made homeless. Data on the number of people affected, however, lack consistency and are not available for all disaster episodes. The most comprehensive source is the EM-DAT database. Notably, for the 4,039 events worldwide recorded in the EM-DAT database between January 1990 and July 1998, figures for the number of people 'affected' (including those injured or made homeless) are available for only 2,190 (or 54%).

It is probable that periods earlier than 1990-1998 will have even poorer coverage in available datasets. As the IFRC (1996, p.121) notes, reported figures show the aggregate number of victims increasing over time, but this "*does not necessarily mean that human impact is increasing, but may simply be a reflection of better reporting.*"

Quality of monitoring is also likely to vary between countries. This will bias the results, with those countries with better measurement capability being more likely – all other things being equal – to register greater impact. As the International Federation for Red Cross and Red Crescent Societies notes, "*defining 'persons affected' is extremely difficult, and figures will always rely on estimates, as there are many different standards*" (IFRC, 1994, p.143).

An additional concern with this measure, as with all measures that are based on cumulative figures over a period of time, is that the results will inevitably be influenced by the length of the time period employed.

Deaths Due to Natural Disasters

The number of deaths gives an idea of the severity of disasters, and can be taken as an indication of the overall impact of a disaster. The data are likely to be more reliable than on the number of persons affected, but even these data can be uncertain[3/]. In utilising deaths due to natural disasters to identify more disaster-prone areas, Mitchell (1989, p.11) finds that, "*existing global data sets seriously underestimate natural disaster death tolls*." Also of concern for comparative analysis, Mitchell notes that disaster deaths might be less well documented in poorer countries. In the EM-DAT database, 74% of the events recorded between 1990 and July, 1998 had reported fatalities.

The number of deaths will be considerably affected by a country's ability to defend against the effects of disaster. This will be influenced, of course, by the vulnerability of the population to natural hazards, and the extent and efficacy of mitigation measures in place. For instance, the IRFC (1995) notes that, "*Poor countries or countries containing large proportions of their population living below the poverty line ... suffer high disaster-casualty rates*."

[3/] The number of deaths associated with a disaster is often far from certain. For instance, Kelman (1998, p.110) notes that reported fatalities ranged from 19 to more than 30 persons as a result of the 25 June, 1997, pyroclastic flow from Montserrat's Soufriere Hills volcano. Estimates of deaths due to the eruption of Mount Pinatubo in the Phillipines in 1991 ranged from "approximately 200" to "nearly 500" (Kelman, 1998, p.100). Moreover, many of the deaths that occurred in the Phillipines were a combination to two simultaneous natural events, the volcanic eruption and Typhoon Yunya (Kelman, 1998, p.100), complicating the issue of allocating the number of deaths attributable to each disaster.

A major drawback of this measure is that many disasters that might have far-reaching economic consequences may result in few, if any, casualties, so that economic impact will be underestimated. On the other hand, a localised tragedy might result in a relatively high death toll but limited economic consequences, thereby over-stating the overall impact. Moreover, the number of deaths may represent an increasingly poor proxy for overall impact, since it has been found that as development advances, damages can increase dramatically even as related deaths decline (Diaz and Pulwarty, 1997a).

NATURAL DISASTERS IN THE CARIBBEAN

An attempt has been made to rank a number of Caribbean countries according to historical vulnerability to natural disasters based on the measures discussed above. Despite the various drawbacks outlined above, the demand for information by the countries themselves and by the international community requires a determined effort to identify a suitable measure.

The Number of Natural Disaster Events

Details on the number of major natural disasters in 17 Caribbean countries between 1900 and 1998 are taken from the formidable EM-DAT database available on the internet (CRED, 2000). The total number of events for each country between 1900 and 1998, adjusted for population size, is illustrated in Column 1 of Appendix 1. This suggests that Anguilla and Montserrat are the most susceptible, followed by the St. Kitts and Nevis, British Virgin Islands (BVI), Turks and Caicos Islands (TCI), Dominica and Antigua and Barbuda.

A database covering a similarly long period, 1889-1989, reported in OAS (1997) gives very similar results, shown in Column 2 of Appendix 1. However, it also brings to light certain differences. For instance, the data underlying these results attribute Barbados with a relatively high number of events – most notably seven hurricanes – in comparison with most of the islands of the Lesser Antilles. Most of these small islands are further north than Barbados and are generally considered more prone to hurricanes. They are also of volcanic origin. However, the majority of these islands have only between one and three hurricanes recorded for the period. BVI is reported as having suffered five hurricanes, compared with its directly adjacent neighbour, the United States Virgin Islands, with 16.

Another dataset covering a long period is provided in USOFDA (1993) (Column 3 of Appendix 1). Once again, the figures and ranks are similar but not identical to the other long-term datasets. Notable is the relatively low ranking of BVI.

As previously noted, a primary drawback of utilising data on the number of natural disasters stems from the lack of consideration of the severity of each event. A simple adjustment of dividing through by population size leads to a ranking that is predominantly a reflection of population size, with smaller countries almost inevitably ranking as more vulnerable. Adjusting the number of events for size of population (or, perhaps, land area) seems particularly inappropriate for the Caribbean countries under consideration. The large potential geographical extent of impacts resulting from natural catastrophes such as hurricanes, earthquakes and volcanic eruptions, in comparison to the relatively small size of these Caribbean states, suggests that a large proportion of any country in the sample could be affected by a single disaster. For instance, an event equivalent to that which might impact upon the whole of an island with population of

10,000 could just as well affect an island of 100,000 or even one million (mn). As an example, hurricane Gilbert, in 1988, travelled the full length of Jamaica and is reported as having adversely affected 810,000 of Jamaica's 2.4 mn inhabitants (USOFDA, 1993).

If the number of events is considered independently of population size or land area, there is consensus amongst the various datasets that Jamaica, the largest country in the sample, witnessed the most events during the past 100 years or, more recently, during the past 25 years. Other than this, however, there are marked differences in the ranks deriving from different sources. Unsurprisingly, countries with small populations tend to rank particularly low, illustrating the drawback of assessing vulnerability based on the number of events with no regard to the extent of impact. A notable example is Montserrat, where, hurricane Hugo and the eruption of the Soufriere Hills Volcano are two of only four events recorded in the EM-DAT database for the past 100 years, although both had truly devastating impacts at the national scale.

It is clear from a glance at Appendix 1, Columns 1 to 3, that an assessment of comparative vulnerability to natural disasters can depend significantly on the source employed, even for the relatively straightforward measure of the number of events experienced by each country.

Macroeconomic Impacts

An assessment of the economic impacts of natural disasters in the Caribbean is based on averaging across 21 major natural disasters, listed in the Appendix, that occurred in the Caribbean Development Bank's Borrowing Member Countries between 1970 and 1997. All of these events were hurricanes or severe tropical storms. Montserrat's recent volcanic eruptions have not been included in the analysis due to the lack of a subsequent period with which to compare; recent events in Montserrat are considered separately. Most of the events occurred in the month September, although they range from August through to November. A problem arises in choosing which disasters to include; the inclusion of those with a low impact will reduce the apparent average impact and lead to non-disaster factors exerting greater influence on the results. The events selected in the present study are those associated with a significant degree of impact according to various sources (CRED/CIFEG, 1997; IFRC, 1994; OAS/USAID, 1991; UNEP, 1994 and USOFDA, 1993).

Variations before and after the onset of these disasters were measured for the following economic variables:

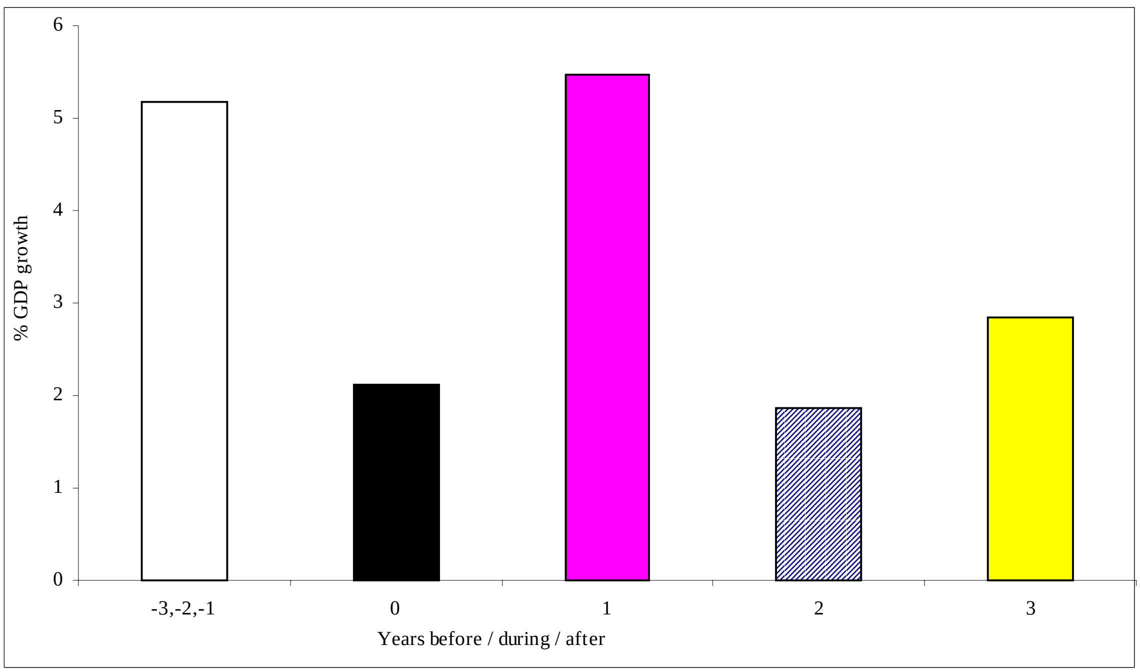
(a) GDP (in real terms);
(b) consumer prices;
(c) exports of goods;
(d) imports of goods;
(e) balance of trade;
(f) net foreign assets;
(g) long-stay tourist arrivals;
(h) cruiseship passenger arrivals;
(i) external debt;
(j) government current expenditure (in real terms); and
(k) government capital expenditure (in real terms).

The following results are generated from a comparison between the three years prior to the event with up to three years following the event, averaged across the 21 events.

GDP

Growth in GDP tended to slow during the year of the event, by 3.1% on average (from 5.4% to 2.3%). This is likely to be associated with reduced productivity resulting from damage to infrastructure and plant, loss of agricultural output, and reduced tourism arrivals during the high, winter season. There was frequently a considerable rebound in GDP growth (by an average of 3.4%) in the year immediately following the event, assisted by a surge in construction and rehabilitation activity, often financed from external sources. There was another slump in the second year following the event (averaging a fall of 3.8%) as the temporary boost in economic activity subsided, with the rate being maintained in the third year. This pattern is illustrated in Figure 1.

Figure 1: Average Annual GDP Growth Rate After Major Natural Disasters, and Average of Previous Three Years, in the Caribbean, 1970-97



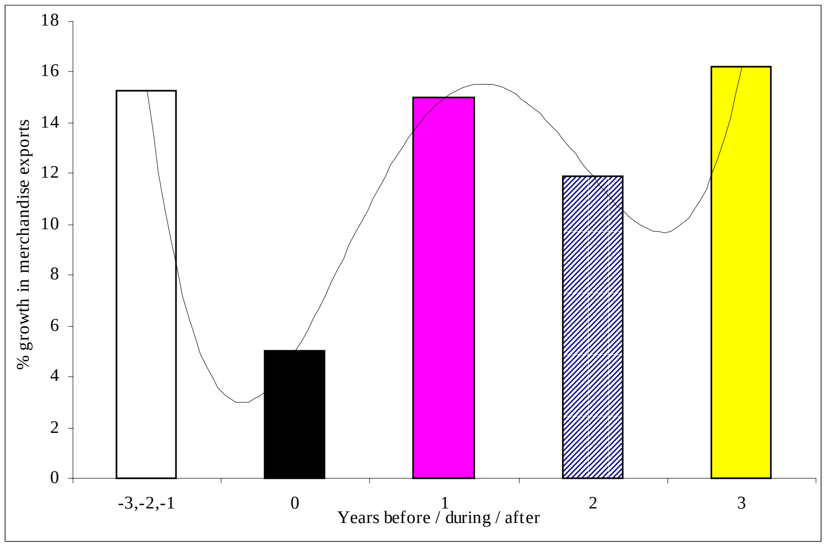
Consumer Prices

There is no significant pattern observable in the response of consumer prices to natural disasters. This is partly due to the already volatile behaviour of prices in many Caribbean economies during the 1970s and 1980s. In addition, selected imports are often exempted from import duties following disasters, which can serve to dampen upward pressure on prices. The average rate of inflation for countries before disasters was 8%, and the average fluctuated between 6.5% and 9% subsequently. Even at the level of the individual disaster episode, rates of inflation rarely showed much recognisable response.

Merchandise Exports

Exports of goods suffered a reduction in the rate of growth of 10%, on average, during the year of the disaster. The growth rate largely returned towards its previous level in the year following the disaster, and maintained relatively high growth in subsequent years. This is illustrated in Figure 2. There are exceptions to this pattern. For instance, sugar exporting countries such as Barbados and St. Kitts and Nevis tended to suffer a greater loss in exports in the following year, since the sugar harvest was complete for the year in which the disasters occurred.

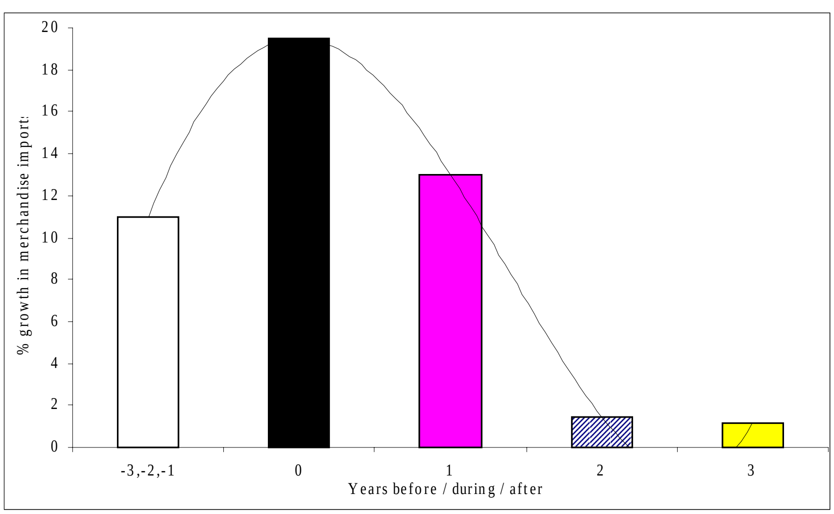
Figure 2: Average Annual Growth in Merchandise Exports After Major Natural Disasters, and Average of Previous Three Years, in the Caribbean, 1970-97



Merchandise Imports

Imports of goods tended to witness a considerable increase in growth during the year of the disaster, of 8.5% on average. This was presumably due to the need to satisfy consumption requirements not met by the reduced local supply, and imports for rehabilitation. Growth rates tended to fall to around their prior level in the subsequent year, and plummet by a further 11.5%, on average, in the second year following the disaster. There was little further change in growth rate in the third year. This pattern is illustrated in Figure 3. The dramatic declines in import growth were associated with reduced economic activity and disposable income.

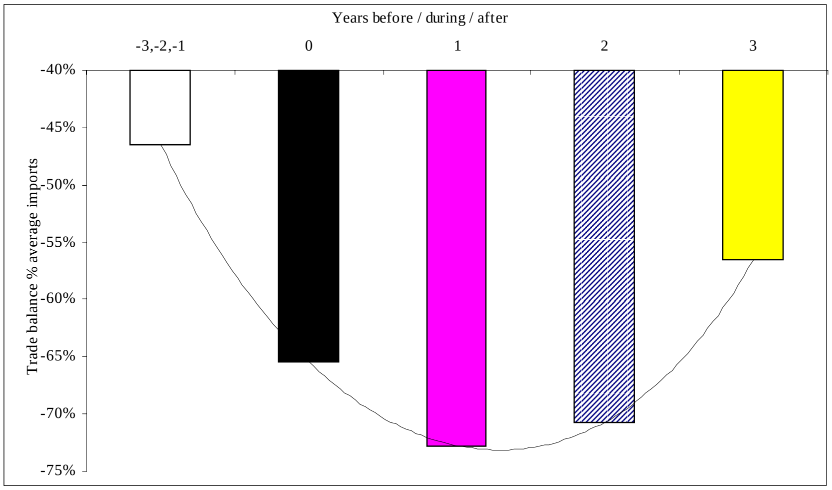
Figure 3: Average Annual Growth in Merchandise Imports After Major Natural Disasters, and Average of Previous Three Years, in the Caribbean, 1970-97



Balance of Trade

Changes in the balance of trade represent the combined effects of shifts in exports and imports. Each year's figure for balance of trade is divided-through by the average level of imports in that country over the seven year period under consideration. Dividing through by imports allows direct comparison between countries, and using the period average for the denominator focuses attention on annual changes in the numerator, i.e. the trade balance.

Figure 4: <u>Average Annual Trade Balance (% Imports) After Major Natural Disasters, and Average of Previous Three Years, in the Caribbean, 1970-97</u>

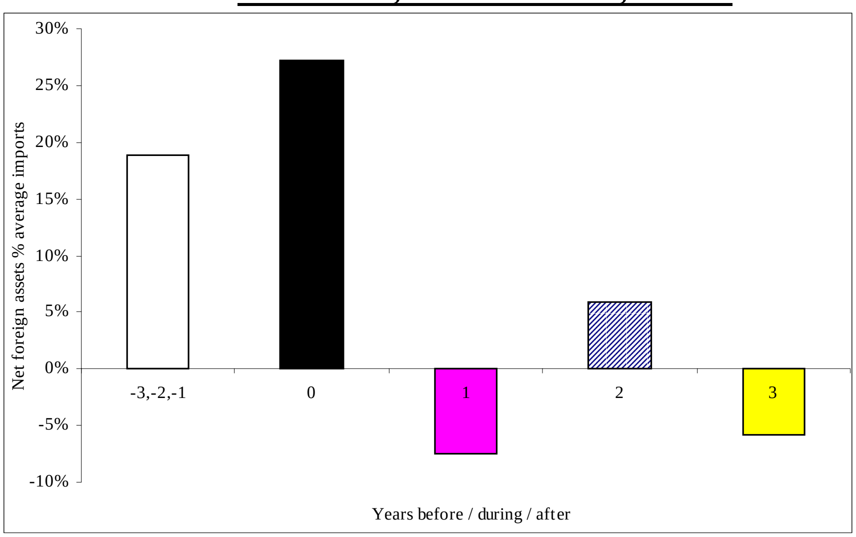


The trade deficit widened, on average, from 46.0% of imports to 65.5% of imports in the year of the disaster As Figure 4 shows, the deficit further deteriorated in the following year, and improved somewhat in the second and third years after the disaster.

Net Foreign Assets

Net foreign assets (NFA) tend to fluctuate around zero, and so are also considered in relation to average merchandise imports over the period. NFA generally rose during the year of the disaster, from 19% to 27% of imports on average. This was presumably due to an influx of relief funds and possibly re-insurance payments. The level of net foreign assets tended to decline dramatically thereafter, as Figure 5 illustrates.

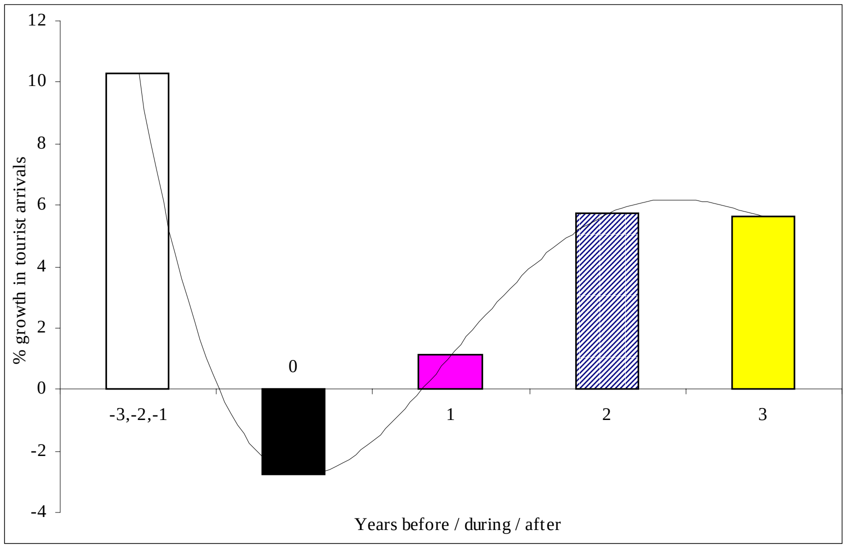
Figure 5: <u>Average Annual Net Foreign Assets (% Imports) After Major Natural Disasters, and Average of Previous Three Years, in the Caribbean, 1970-97</u>



Long-stay Tourist Arrivals

Long-stay tourist arrivals commonly slumped during the year of the disaster, with a loss of potential visitors during the high, winter, season, leading to an average drop in the growth rate of around 13%, with numbers ***falling in absolute terms*** by 2.8% on average. There was a tendency for growth in visitor numbers to pick up slowly in subsequent years, but this followed a very significant initial drop and, on average, rates of growth did not reach previous levels even after three years. This pattern is illustrated in Figure 6.

Figure 6: Average Annual Growth in Long Stay Tourist Arrivals After Major Natural Disasters, and Average of Previous Three Years, in the Caribbean, 1970-97



Cruiseship Passenger Arrivals

Cruiseship passenger arrivals showed an average drop in growth during the year of the disaster compared to the three previous years. However, cruiseship passenger arrivals were volatile throughout the sample period, making it difficult to distinguish any genuine impact of natural disasters. Quantified measures of impact, therefore, are not attempted.

External Debt

External debt growth rates averaged 17.6% in the three years leading up to each disaster, rising to 20.6% during the year of the disaster, and dropping to around 13.5% in subsequent years. The initial rise may be attributable to emergency loans provided for disaster recovery. However, external debt rarely grows at a constant rate, due to the 'lumpiness' of loan approvals and disbursements, making increases due to natural disaster impacts difficult to isolate.

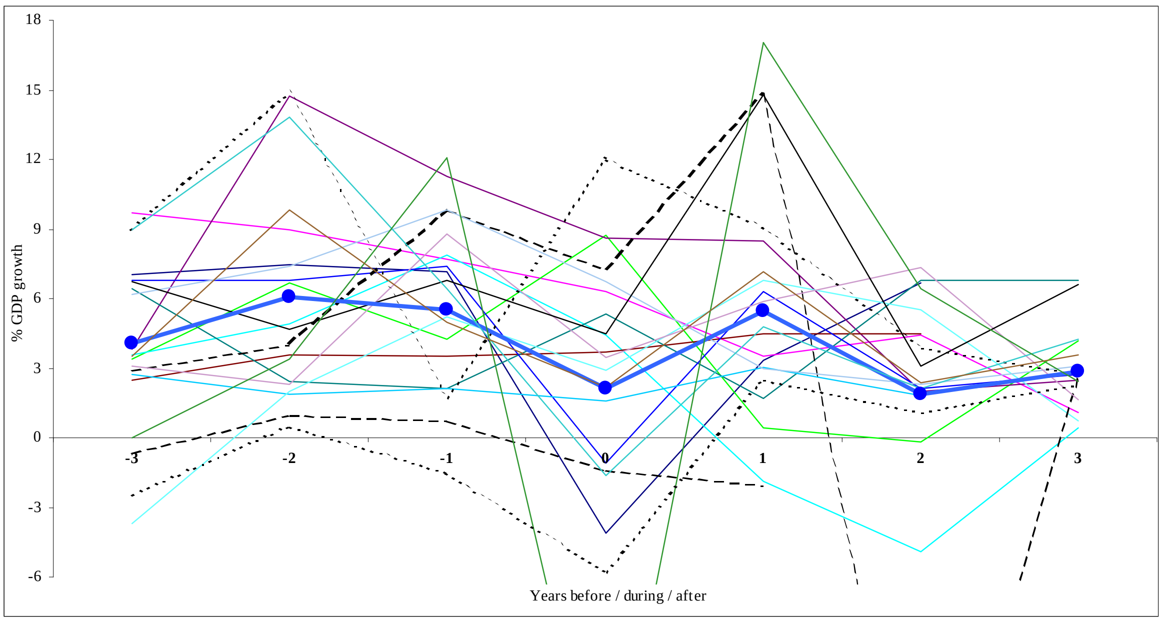
Government Expenditure

The only relationships discernible between natural disasters and government expenditure were the tendency for more rapid growth in capital expenditure during the year of the disaster, and the decline of current expenditure two years after the disaster. However, the growth rate of capital expenditure tends to fluctuate widely between all years, regardless of natural disasters, and current government expenditure is also volatile. This makes it difficult to attribute any shifts in expenditure to the occurrence of a particular event.

Summary of Macroeconomic Impacts

The degree to which the broad patterns outlined above mask huge differences between each event is illustrated in Figure 7. This Figure shows the rate of growth in GDP for the three years preceding each disaster, for the year of the event, and for each of the three years after the event. The extent to which individual cases differ from the regional average (the thicker line with markers) is very apparent. This is explained by many factors, including the differential delay in impact in different countries, and other events unrelated to the natural disaster that lead to anomalous changes in the variables.

Figure 7: <u>Countries' Annual GDP Growth Before and After Major Natural Disasters Occurring in the Caribbean Between 1970 and 1997</u>



There are many anomalies in the data series that lead to counter-intuitive results. In addition to individual instances, it seems that the occurrence of large hurricanes such as Allen (1980) and Hugo (1989), a year or two before the onset of world recession, might have influenced the results. Declines in GDP and other variables can be expected during such periods of recession (1981-82 and 1991-92), and may not be attributable solely to prior disasters.

The range of individual and broad-scale anomalies highlights the futility of assuming that all other factors – internal and external – remain unchanged during the period leading up to, and following, a natural disaster. Each event needs to be considered separately and the circumstances surrounding macroeconomic changes carefully analysed.

Nonetheless, some impacts are more statistically significant across the sample than others. The results of average growth rates or adjusted variables for the years prior to and following the disasters are provided in Table 1. The results of t-tests, assessing the significance of the difference in these variables before and in each year after the disaster, are also provided. The majority of the results are ***not*** significant at the 5% level for a two-tailed test[4/]. The results that are significantly different in each year, compared to the prior three years, are highlighted in Table 1. Results that are less significant, but which have a p-value of less than 25% – indicating a relatively low probability that the difference between the year in question and the years prior to the disaster occurred by chance – are in italics.

Table 1: Average Impact on Variables, and Tests of the Significance of the Impact

Year	Inflation	GDP growth	NFA % imports	Export growth	Import growth	Trade Bal. % import	Govt. current exp. growth	Govt. capital exp. growth	Ext'l debt growth	Long stay tourism growth	Cruise pass. growth
Average across countries											
-3,-2,-1	8.1	5.4	19.0%	15.3	11.0	-46.0%	5.2	9.5	17.6	10.3	16.0
0	9.0	2.3	27.1%	5.0	19.5	-65.5%	7.2	26.2	20.6	-2.8	12.1
1	7.6	5.7	-7.5%	15.0	13.0	-72.7%	7.6	1.0	13.5	1.1	9.3
2	6.5	1.9	5.8%	11.9	1.5	-70.7%	0.1	0.7	13.5	5.7	8.8
3	7.9	3.0	-5.9%	16.2	1.1	-56.5%	5.4	5.6	16.2	5.6	11.9
T-test of difference between year and 3 years prior to the disaster											
0	0.36	-1.96	0.35	-1.52	**2.48**	**-2.32**	0.74	1.28	0.44	**-4.33**	-0.46
1	-0.20	0.16	-1.54	-0.05	0.53	**-3.03**	1.11	-1.30	-0.68	**-2.95**	-0.80
2	-0.75	**-2.22**	-0.80	-0.46	**-2.93**	**-2.91**	-1.91	-0.96	-0.68	-0.94	-0.80
3	-0.05	**-2.99**	-0.91	0.16	**-3.03**	-1.22	0.10	-0.30	-0.22	-1.53	-0.51
P-values for T-test											
0	73%	***6%***	73%	***14%***	**2%**	**3%**	47%	***22%***	66%	**0%**	65%
1	84%	88%	***14%***	96%	61%	**1%**	28%	***21%***	50%	**1%**	43%
2	46%	**4%**	43%	65%	**1%**	**1%**	***7%***	35%	50%	36%	43%
3	96%	**1%**	38%	87%	**1%**	***24%***	92%	77%	83%	***14%***	61%

An analysis of the results suggests that, on average:

(a) impacts on GDP were significant, particularly in the second and third years (presumably because differential delays in the year of the disaster and the year immediately were evened out);

(b) negative impacts on the trade balance were significant, primarily due to the initial increase and subsequent decrease in imports;

(c) negative impacts on long-stay tourism were highly significant immediately following the disaster; and

(d) an initial peak in government capital expenditure growth was followed by low growth rates, while government current expenditure showed a marked drop in growth two years after the disaster.

[4/] The cut-off level is a t-statistic of 2.04. Due to data limitations, not all series have 21 entries, the lowest sample size being 15 in the third year, and the lowest sample size for the three years prior to disaster being 17. This gives the minimum degrees of freedom of 15+17-2 = 30.

While broad patterns across countries can, therefore, be discerned, the results differ widely for individual events. The anomalous results due to non-disaster related effects are smoothed over in assessing average impacts across events. However, if each event is considered separately, very different responses to disasters will be observed. This approach is not suitable, therefore, for comparing individual countries' relative vulnerability to natural disasters.

Montserrat

The recent devastating volcanic activity at Montserrat's Soufriere Hills deserves special mention. Even as the country was recovering from the severe impacts of hurricane Hugo in 1989, the already dampened rates of economic growth (of between 0.9% and 2.6% from 1992-94) collapsed to -7.6% and -21.4% in 1995 and 1996. With evacuation of much of the island, including the emptying of the capital, Plymouth, in 1997, this slumped to –26.5%. These dramatic declines highlight the massive impacts – to all aspects of life – that natural disasters can have, and the vulnerability of the entire economies of small island states.

However, even as economic growth declined, merchandise exports increased dramatically in 1995 and 1996 (by 317% and 94%) thanks to a surge in partial milling and export of rice from Guyana en-route to the EU via the lucrative Dependent Territories Route.

The example of Montserrat's rising exports is just one illustration of the inability to directly compare variables across disaster events, without analysis of other factors that influence these variables. In the seven-year window that is the focus for analysis, other parameters do ***not*** remain unchanged. Some changes in key macroeconomic variables will ***not*** be attributable to the natural disaster.

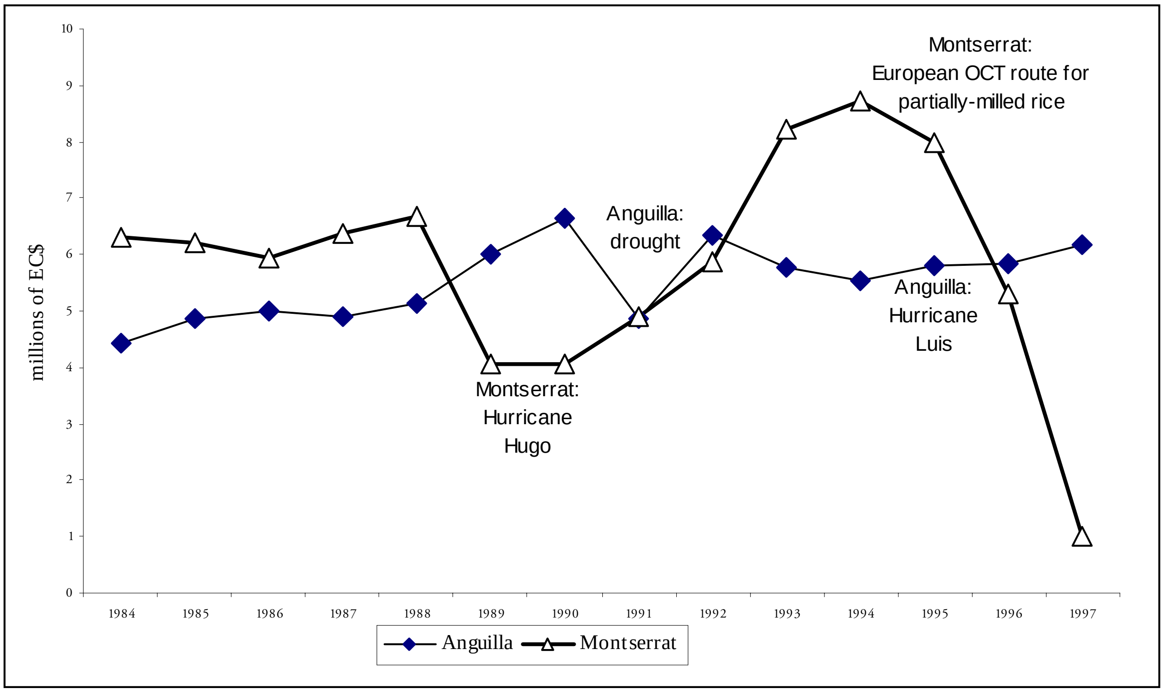
Agricultural Production Volatility

A ranking of countries based on instability of agricultural GDP between 1980 and 1998 is presented in Column 7 of Appendix 1. Agricultural output is measured here in monetary terms, as value-added in agriculture (or agricultural GDP). The results are not significantly different from results that derive from the use of a physical measure of the volume of agricultural output. One problem with this measure is lack of data. The high rank of TCI, for instance, is based on a wholly inadequate sample of just seven years of agricultural GDP.

Problems highlighted in Section B with attributing instability in agricultural output to natural disasters, and then extrapolating this instability to represent impacts on the economy as a whole, suggest that this measure is a poor representation of vulnerability to natural disasters.

To illustrate some of the problems associated with employing this measure, agricultural GDP for Anguilla and Montserrat between 1984 and 1998 is shown in Figure 8. The sharp dip in Anguilla's agricultural production in 1991, of -27.1%, was associated with a drought. Total GDP also fell by -3.6% that year. However, the drought was not considered a disaster, and the association with a fall in total GDP is largely coincidental. Despite the dramatic decline in agricultural output, this accounted for less than one tenth of the total decline in GDP, due to the fact that agriculture accounted for only 4.9% of total GDP in 1990. The major cause of the economic slump was a sharp drop in tourist arrivals due to the Gulf War, leading to a fall in tourism expenditure and reduced investment in tourism plant (CDB, 1992). Moreover, it was marine fishing that contributed most to the decline in agricultural output; a sector that would have been relatively immune to the drought.

Figure 8: Agricultural GDP (constant prices), Anguilla and Montserrat, 1980-97



In contrast to the apparent association between the drought of 1991 and agricultural output, the impact that hurricanes Luis and Marilyn had on the island in 1995 did not register in terms of agricultural output.

The case of Montserrat shows that agricultural output did indeed reflect the devastating impact of hurricane Hugo in 1989. However, there was a period of abnormal growth in 1993, 1994 and even 1995 when volcanic activity began to cause serious disruption on the island. The rapid increase in agricultural GDP stemmed from a short-lived market opportunity whereby rice from Guyana was partly milled to allow duty free access to the EU. This registered as agricultural output, and the operation was maintained in 1995 as one of the remaining industries on the island.

The estimates of agricultural output volatility for the Caribbean are not, therefore, considered in detail. Suffice it to say that the ranks of a number of countries, such as Jamaica, Antigua and Barbuda, and Belize, are markedly different from their ranks based on other measures.

Damage Costs

A study by the United Nations Disaster Relief Organisation (UNDRO) reports on damage costs as a proportion of countries' GDP for natural disasters between 1970 and 1989 (UNDRO, 1990). The results of the UNDRO study (as reported in UNEP, 1994), adjusted for population size, are presented in Column 6 of Appendix 1. Figures are provided for less than half of the sample of Caribbean countries. Among these, Montserrat ranks as by far the most vulnerable, based solely on the devastating impact of hurricane Hugo in 1989. Dominica ranks as relatively vulnerable, followed by St. Lucia and Jamaica (despite its large population size). This measure of natural disaster vulnerability is used by Briguglio (1995) as part of an aggregate index of economic vulnerability, and partly explains the omission of many Caribbean countries from Briguglio's study.

The paucity and poor quality of data on damage costs, as outlined in Section B, precludes the use of this measure for assessing comparative vulnerability to natural disasters.

Number of Persons Affected by Natural Disasters

Data on the number of persons affected by natural disasters for the period 1990-98 are taken from the EM-DAT database (CRED, 2000). Cumulative numbers affected as a proportion of 1995 population, for those events for which data are provided, are presented in Column 5 of Appendix 1. This shows Antigua and Barbuda and Montserrat as by far the most vulnerable, followed by Dominica and Guyana. The high placing of Guyana is due substantially to a figure for the number affected equivalent to the entire population for the El Nina-induced drought of 1997-98. Noticeable, also, is the comparatively low ranking of TCI compared to its relatively high ranking based on the number of events suffered per person.

Deaths Due to Natural Disasters

Data on the number of deaths due to natural disasters for the period 1990-98 are also taken from the EM-DAT database (CRED, 2000). Cumulative deaths as a proportion of the 1995 population are presented in Column 4 of Appendix 1. The ranking is considerably different to that for the number of people affected, from the same source. This may be partly explained by the better – but far from complete – coverage of events for the data on deaths. It will also be due to the character of the events affecting each country and a range of features that influence how a given event impacts upon a particular country. Noticeable are the comparatively high rankings of Dominica, Belize and, especially, St. Vincent and the Grenadines, suggesting a relatively large number of deaths resulting from each event. In contrast, the low ranking of BVI, with zero deaths, suggests considerable protection against hurricanes.

Combining the Number of Persons Affected and the Number of Deaths

A compromise solution employed to address the thorny issue of identifying a suitable measure of comparative vulnerability to natural disasters combines the measures of number of persons affected and number of deaths. The number of persons affected is theoretically a better measure of vulnerability since it reflects broad social and economic consequences. In practice, however, difficulties in estimation lead to large gaps in the data and questionable comparison between countries and over time. In contrast, the number of deaths is relatively accurately recorded and more comparable between events, but is a poorer proxy for broad social and economic impacts. Combining these two variables is far from an ideal solution but it is hoped that it may give a more reliable indication of vulnerability to natural disasters than will the application of any of the individual measures outlined above.

The time period is restricted to 1950 to 1998, due to the poor quality of data prior to 1950. The database is manipulated in order to include disasters for which no relevant figures are available. The average number of people affected (or number of deaths) is calculated for each country from those events for which data ***are*** available. This average is multiplied by the number of events experienced by the country during the selected period. In this manner, each disaster is attributed with the average degree of impact experienced by the country during the period. The cumulative impact for each country will inevitably be under- or over-stated, but there is no systematic bias. In contrast, using raw data will be biased towards understating the cumulative impact of disasters on countries for which fewer data are available.

Each of these manipulated series is normalised so that it ranges between zero and one, maintaining the proportional distances between entries[5/]. This allows series of different dimensions to be combined. A simple process of averaging the two figures for each country is employed, and the resulting series is re-normalised to better illustrate the distances between countries[6/].

The results for the adjusted series of the number of people affected, presented in Column 9 of Appendix 1, are very similar to those emerging from analysis of a longer time series without adjusting for data omissions (Column 5). The major difference - the lower ranking of Guyana - stems from the deliberate omission of what is regarded as an unrealistically high figure recorded for 1997 which, when applied to years for which data are not available, would significantly overstate Guyana's vulnerability.

The results for the adjusted series of the number of deaths, presented in Column 10 of Appendix 1, show marked differences to those of the unadjusted data for the longer period (Column 4). Montserrat's rank, for instance, is higher due to the extensive impacts experienced since 1989 that are not matched by events prior to 1950. In contrast, the ranks of Dominica and Jamaica are considerably lower, indicating comparatively fewer deaths in the latter half of the century.

Results for the combined measure, for 1950 to 1998, are presented in Column 11 of Appendix 1. The ranks concur largely with those derived from the range of measures discussed above. Montserrat is ranked highest, followed by Antigua and then Belize, Dominica and Anguilla.

Concerns regarding the reliability of data prior to 1970 led to a combined measure being calculated for the period 1970 to 1998. The results are presented in Column 12 of Appendix 1. These are similar to the results of the combined measure for 1950 to 1998, the notable difference being the lower ranking of Dominica, Jamaica and Guyana. Employing an alternative time period illustrates that broad patterns of estimated vulnerability remain roughly the same but that there is inevitably some shift in the ranking of individual countries.

Expert Analysis

The possibility has not been considered, up this point, of expert analysis based on the consideration of a wide array of historical data, information on present characteristics of countries, and predictions of future events.

A major drawback of any use of purely historical information is highlighted by the case of Montserrat. According to OAS/USAID (1991), Montserrat was witness to only one major volcanic eruption during the past 10,000 years (in comparison with, for example, 210 eruptions in St. Vincent). An assessment based on historical frequency would have suggested a low degree of

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[5/] Normalisation involves subtracting the minimum value from each entry of a series in turn, and dividing the result by the difference between the maximum and minimum values of the series.

[6/] A simple averaging procedure assumes that equal weight should be applied to both series. This assumption could be further explored through statistical analysis, but a simple aggregation is considered sufficient for the broad conclusions that will be drawn from the analysis.

vulnerability to volcanic eruption and yet Montserrat has been decimated by volcanic activity since 1995. This might have been reflected in an expert analysis of the likelihood of catastrophic events. In the case of hurricanes, the frequency and intensity of such extreme climatic events is expected to increase in future decades due to a combination of global warming and natural cycles in hurricane activity. The evidence suggests that, "*the period of the 1930s to 1950s saw a high level of hurricane activity in the western Atlantic ... Subsequent decades experienced a slowdown from the level of tropical storm activity ... In recent years, there have been indications that the recent period of relatively low Atlantic tropical cyclone activity may be ending*," (Diaz and Pulwarty, 1997b, p.285). Recent historical evidence, therefore, may be a poor predictor of future activity.

A study is being carried out by CRED into comparative vulnerability of countries throughout the world to natural disasters, based on historical analysis of a broad range of natural disaster events. Results for selected Caribbean countries, drawn from the preliminary results of this study, are presented in Column 8 of Appendix 1 (CRED, personal communication, 2000). Many of the results do not conform to those generated from other measures as outlined above. For instance, Trinidad and Tobago ranks considerably higher, as do St. Vincent and the Grenadines and Jamaica. Countries ranking lower than might be expected include Anguilla, Antigua and Barbuda, Belize and St. Kitts and Nevis. These results are preliminary but they do serve to indicate the difficulties in reconciling the results of alternative methodologies.

Another form of expert analysis that has been applied to just three Caribbean countries is the Caribbean Disaster Mitigation Project's estimation of 'Probable Maximum Loss' of critical infrastructure (OAS, 2000). This combines information on location and quality of units of infrastructure with the predicted likelihood of hurricanes with particular wind speeds. The analysis is only applied to the public sector, and the use of replacement costs to aggregate across types of infrastructure does not strictly measure the extent of economic impact or the value of the losses to society. However, it is a very thorough study and is likely to represent a significant improvement on considering historical data in isolation.

The results of the Probable Maximum Loss study are dramatically different for the three countries. Based on a maximum credible event with a return period of 50 years and a prediction limit of 50%, the estimated losses as a percentage of the estimated value of infrastructure sampled are 44% for Dominica, 24% for St. Kitts and Nevis, and 12% for St. Lucia.

Overview of Comparative Vulnerability to Natural Disasters in the Caribbean

Analysis of historical exposure to natural disasters, as outlined in Columns 1 to 6 and 9 to 12 of Appendix 1, leads to an inconclusive ranking of countries. However, bearing in mind the significant drawbacks highlighted in the all of the measures utilised, a very general pattern can be discerned. The limited, and at times conflicting, evidence suggests that Montserrat has been the most affected by natural disasters, relative to country size. Based primarily on the results of the compromise solution that are presented in Column 11 of Appendix 1, the next most affected have been Anguilla, Antigua and Barbuda, Belize and Dominica. Moderately affected countries have been BVI, Jamaica, St. Kitts and Nevis, St. Lucia and St. Vincent and the Grenadines. Less affected countries have been Bahamas, Barbados, Cayman Islands, Grenada, Guyana, Suriname Trinidad and Tobago and TCI.

This summary is based upon a second-best measure of comparative vulnerability, and does not concur with preliminary results of expert analysis[7/].

CONCLUSION

Assessing vulnerability to natural disasters boils down to predicting the likelihood of events occurring in the future, and the extent of their impact. This is a notoriously difficult exercise. The analysis in the present paper highlights the considerable difficulty in identifying a single acceptable measure of comparative vulnerability to natural disasters. A range of different measures is considered, producing varying and at times conflicting results. The time period included in historical analysis is equally as important as the measure used. A longer time period is preferable, given the long return-periods associated with major events, but data are extremely limited, particularly for estimates of disaster impacts. The unsatisfactory rationale underlying the choice of time period in the present study has been data availability.

However, there is an immediate demand for information on comparative vulnerability. The results presented in Column 11 of Appendix 1 represent a compromise solution derived from readily available information. These results are based on combining data on number of persons affected by, and number of deaths due to, natural disasters between 1950 and 1998, adjusted to account for gaps in the data.

Several broad conclusions can be drawn from the study. Firstly, some countries within the Caribbean can be identified as having been particularly affected by natural disasters in the relatively recent past. Secondly, quantitative analysis based exclusively on assessment of historical episodes is insufficient for deriving a robust ranking of comparative vulnerability to natural disasters. Thirdly, expert analyses of comparative vulnerability are ongoing and promise to provide a more robust comparative ranking.

[7/] A CRED/CIFEG (1997, p.131) report suggests that Jamaica and St. Vincent and the Grenadines are particularly at risk within the Caribbean with regard to natural disasters (which concurs with the preliminary results of the recent CRED study). The emphasis on St. Vincent and the Grenadines does not seem to concur with the evidence this century provided by the range of measures considered above. However, it might reflect longer-term evidence. For instance, according to OAS/USAID (1991), St. Vincent and the Grenadines experienced 210 volcanic eruptions in the past 10,000 years, as compared with the next highest, Dominica and St. Kitts and Nevis, each having experienced only four.

REFERENCES

Briguglio, L. (1995), ‘Small Island Developing States and Their Economic Vulnerabilities’, *World Development*, 23(9), 1615-1632.

Brown, H.A. (1994), ‘Economics of Disasters with Special Reference to the Jamaican Experience’, Working Paper Series No. 2, Insights in Environment and Development, Centre for Environment and Development, University of the West Indies, Jamaica.

CDB (1992), ‘*Annual Report, 1991*’, Caribbean Development Bank, Barbados.

CRED (undated), ‘*CRED International Database on Disasters: EM-DAT*’, Centre for Research on the Epidemiology of Disasters, Catholic University of Louvain, Belgium.

CRED (1997), ‘Assessment of the Economic Impact of Natural and Man-Made Disasters’, Expert Consultation on Methodologies, 29-30 September, 1997, Brussels, Centre for Research on the Epidemiology of Disasters, Catholic University of Louvain, Belgium.

CRED (2000), ‘The OFDA/CRED International Disaster Database’, Centre for Research on the Epidemiology of Disasters, Catholic University of Louvain, Belgium, available at www.md.ucl.ac.be/cred/welcome.

CRED/CIFEG (1997), ‘Diagnostic Study for the Dipecho Action Plan for Central America and the Caribbean’, report to the ECHO Programme for Disaster Prevention, Mitigation and Preparedness (DIPECHO), Centre for Research on the Epidemiology of Disasters (CRED) and the International Center for Training Exchanges in the Geosciences (CIFEG), April, 1998.

D’Ercole, R. and Pigeon, P. (1998), ‘Natural Disasters in South East Asia and Bangladesh: Vulnerability Risks and Consequences’, report to the ECHO Programme for Disaster Prevention, Mitigation and Preparedness (DIPECHO), Centre for Research on the Epidemiology of Disasters (CRED) and the International Center for Training Exchanges in the Geosciences (CIFEG), March.

Diaz, H.F. and Pulwarty, R.S. (1997a), ‘Decadal Climate Variability, Atlantic Hurricanes, and Societal Impacts: An Overview’, in Diaz, H.F. and Pulwarty, R.S. (eds.), *Hurricanes*, 3-14.

Diaz, H.F. and Pulwarty, R.S. (1997b), ‘Closing Remarks’, in Diaz, H.F. and Pulwarty, R.S. (eds.), *Hurricanes*, 285-288.

DIPECHO (1999), ‘Action Plan for the Caribbean’, Programme of Disaster-Preparedness – European Community Humanitarian Office, available at www.disaster.info.desastres.net/action_plan/action_plan3.html#3.

IFRC (1994), *World Disasters Report 1994*, International Federation of Red Cross and Red Crescent Societies, Oxford University Press, Oxford.

IFRC (1995), *World Disasters Report 1995*, International Federation of Red Cross and Red Crescent Societies, available at: www.ifrc.org/home.htm.

IFRC (1996), *World Disasters Report 1996*, International Federation of Red Cross and Red Crescent Societies, Oxford University Press, Oxford.

Kelman, I, (1998), 'Role of Technology in Managing Vulnerability to Natural Disasters, with Case Studies of Volcanic Disasters on Non-Industrialised Islands', thesis submitted in conformity with the requirements for the degree of Master of Applied Science, Graduate Department of Engineering, University of Toronto.

Kreimer, A. and Munasinghe, M. (1991), 'Managing Environmental Degradation and Natural Disasters: an Overview', in A. Kreimer and M. Munasinghe (eds.), *Managing Natural Disasters and the Environment*, World Bank, Washington, D.C.

Mitchell, J.K. (1989), 'Where Might the International Decade for Natural Disaster Reduction Concentrate its Activities?', DNDR 2, Natural Hazards Research and Applications Information Center, Rutgers University, September.

OAS/USAID (1991), *Primer on Natural Hazard Management in Integrated Regional Development Planning*, Department of Regional Development and Environment of the Organization of American States, and Office of Disaster Assistance of the United States Agency for International Development, Washington D.C.

OAS (1997), 'Natural Hazards in the Caribbean', Appendix to the Caribbean Disaster Mitigation Project report, 'Planning to Mitigate the Impacts of Natural Hazards in the Caribbean', Organization of American States, October.

OAS (2000), 'A Probable Maximum Loss Study of Critical Infrastructure in Three Caribbean Island States', Organization of American States, available at www.oas.org/en/cdmp.

Pantin, D.A. (1997), 'Alternative Ecological Vulnerability Indices for Developing Countries with Special Reference to Small Island Developing States (SIDS)', report for the United Nations Department of Economic and Social Affairs, Sustainable Economic Development Unit, University of the West Indies, Trinidad, November.

Pulwarty, R.S. and Riebsame, W.E. (1997), 'The Political Ecology of Vulnerability to Hurricane-Related Hazards', in Diaz, H.F. and Pulwarty, R.S. (eds.), *Hurricanes*, 185-214.

UNCTAD (1983), *The Incidence of Natural Disasters in Island Developing Countries*, United Nations Conference on Trade and Development, Geneva.

UNDESA (1999), 'Vulnerability and Poverty in a Global Economy', report of the Committee for Development Policy on the first session (26-30 April, 1999), United Nations Department of Economic and Social Affairs, New York.

UNDRO (1986), 'Social and Sociological Aspects', Volume 12 of 'Disaster Prevention and Mitigation: A Compendium of Current Knowledge', Office of the United Nations Disaster Relief Co-ordinator, United Nations, New York.

UNDRO (1990), 'Preliminary Study on the Identification of Disaster-prone Countries based on Economic Impact', United Nations Disaster Relief Organisation, Geneva.

UNEP (1994), 'Environmental Data Report, 1993-94, prepared for the United Nations Environment Programme by the GEMS Monitoring and Assessment Research Centre, London, UK, in co-operation with the World Resources Institute, Washington, D.C. and the UK Department of the Environment, London, UK.

USOFDA (1993), *Disaster History: Significant Data on Major Disasters Worldwide, 1900-Present*, United States Office of Foreign Disaster Assistance, Washington, D.C.

EVENTS INCLUDED IN THE ANALYSIS

	AG	AN	BA	BD	BZ	BVI	DO	JA	MO	SK	SL	SV
1970												
1971												
1972												
1973												
1974					Fifi							
1975												
1976												
1977												
1978												
1979							David					
1980				Allen				Allen			Allen	Allen
1981												
1982												
1983												
1984							Klaus					
1985												
1986												
1987												Emily
1988								Gilbert			Gilbert	
1989		Hugo				Hugo	Hugo		Hugo	Hugo		
1990												
1991												
1992			Andrew									
1993												
1994												
1995	Luis					Luis	Luis		*Soufriere Hills Volcano*	Luis		
1996								Storm				
1997												