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High Consumption Volatility

The Impact of Natural Disasters?

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Abstract

A history of repeated external and domestic shocks has made economic insecurity a major concern across the Caribbean region. Of particular concern to all households, especially the poorest segments of the population, is the exposure to shocks that are generated by catastrophic events or natural disasters.

Auffret shows that despite high consumption growth, the Caribbean region suffers from a high volatility of consumption that decreases household welfare. After presenting some empirical evidence that consumption volatility is higher in the Caribbean region than in the rest of the world, he makes some empirically testable inferences that help explain consumption volatility. The author develops a conceptual framework for analyzing the effects of catastrophic events on household and aggregate welfare. According to this framework, the volatility of consumption comes from production shocks that are transformed into consumption shocks mostly because of underdeveloped or ineffective risk-management mechanisms. Auffret conducts an empirical analysis of the impact of catastrophic events on 16 countries (6 from the Caribbean region and 10 from Latin America) from 1970–99 and shows that catastrophic events lead to:

- A substantial decline in the growth of output.
- A substantial decline in the growth of investment.
- A more moderate decline in consumption growth (most of the decline is in private consumption, while public consumption declines moderately).
- A worsening of the current account of the balance of payments.

This paper—a product of the Economic Policy Sector Unit, Latin America and the Caribbean Region—is part of a larger effort in the region to assess the impact of catastrophic events on welfare. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Kevin Tomlinson, room I4-403, telephone 202-473-9763, fax 202-676-1494, email address ktomlinson@worldbank.org. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at pauffret@worldbank.org. January 2003. (33 pages)

High Consumption Volatility: The Impact of Natural Disasters ?

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High Consumption Volatility: The Impact of Natural Disasters ?

The Caribbean region suffers from a high degree of economic volatility. A history of repeated external and domestic shocks has made economic insecurity a major concern across the region. Of particular concern to all households, especially the poorest segments of the population, is the exposure to shocks that are generated by catastrophic events or natural disasters.

After presenting some empirical evidence that consumption volatility is higher in the Caribbean region than in the rest of the world, the paper makes some empirically testable inferences that help explain consumption volatility (Section A), the paper develops a conceptual framework for analyzing the impacts of catastrophic events on household and aggregate welfare before testing the data empirically (Section B).

A. Aggregate Volatility in the Caribbean Region

A.1. Volatility of Consumption: An International Comparison

Despite a high level of consumption growth, the Caribbean region also suffers from a measurably high volatility of consumption (Box 1.1). Per capita consumption growth averaged 2.5 percent in the Caribbean region during the period 1960-97, comparable to average growth for the OECD countries and above that of all other regions with the exception of East Asia and the Pacific (Table 1.1). However, average per capita consumption volatility[1] in the Caribbean region is higher than in any other region of the world. Table 1.1 shows that the volatility of per capita consumption in the Caribbean region is four times higher than it is in industrialized economies, well above the levels of other regions like Asia, non-OECD Europe and Latin America.

The Caribbean region comprises different economies whose respective performances, in terms of consumption volatility, have been equally diverse (Table 1.1). The volatility of per capita consumption has been highest in Guyana and St. Lucia (with standard deviation exceeding 10 percent) and lowest in Grenada and Haiti (below 6 percent).

[1] The standard deviation of per capita consumption growth is usually referred to as the volatility of per capita consumption (See Box 1.1).

Box 1.1: Defining and Measuring Consumption Volatility

In this report, we assume that per capita consumption follows a geometric Brownian motion with drift represented by $\frac{dc}{c} = \mu \cdot dt + \sigma \cdot dZ$ where dZ is a standard Brownian motion with expectation and variance equal to 0 and dt, respectively.[1/ 2/] The expected instantaneous per capita consumption growth is μ while σ^2 (resp. σ) represents the variance (resp. standard deviation) of consumption growth. The variable σ is usually referred to as the volatility of per capita consumption. Using Ito's lemma, it can be shown that $d(Log\ c_t) = \left(\mu - \frac{1}{2} \cdot \sigma^2\right) \cdot dt + \sigma \cdot dZ$. Hence, $c_t = c_0 \cdot \exp\left[\left(\mu - \frac{1}{2} \cdot \sigma^2\right) + \sigma \cdot \left[Z(t+1) - Z(t)\right]\right]$ and $Log\left(\frac{c_{t+1}}{c_t}\right) = \left(\mu - \frac{1}{2} \cdot \sigma^2\right) + \sigma \cdot \left[Z(t+1) - Z(t)\right]$. Consequently, the variance of per capita consumption growth and the expected instantaneous consumption growth are respectively given by $\sigma^2 = Var\left[Log\left(\frac{c_{t+1}}{c_t}\right)\right]$ and $\mu = E\left[Log\left(\frac{c_{t+1}}{c_t}\right)\right] + \frac{1}{2} \cdot \sigma^2$ where Var and E refer to the unconditional variance and expectation. This consumption process -- which has the advantage of not violating the assumption of non-negative consumption -- can be derived as the optimal outcome in a general equilibrium model with constant return-to-scale technologies defined by $\frac{dY}{K} = a \cdot dt + s \cdot dZ$ where K represents the stock of capital, dY is the instantaneous output and the technological coefficients $\{a, s\}$ are exogenously specified constants with $s > 0$ (Auffret, 2002).

The lognormal model is consistent with the properties of historical consumption data. Indeed, historical data show that both the skewness and kurtosis of per capita consumption growth are not statistically different from those of the normal distribution (skewness and kurtosis of the normal distribution are 0 and 3 respectively). The Table below reports sample statistics for yearly per-capita consumption growth. The skewness estimates are negative for all regions but are not statistically different from 0. Indeed, since there are 30 observations, the standard error for the skewness estimate under the null hypothesis of normality is $\sqrt{6/30} = 0.45$.[3/] Also, yearly per-capita consumption growth have a kurtosis which, in most regions, is not significantly different from the one of the normal distribution. Indeed, the standard error for the kurtosis estimate is $\sqrt{24/30} = 0.89$.

Table: Per Capita Consumption Statistics: Regional Comparison

Region (unweighted average)	Per Capita Consumption			
	Growth (%) μ	Variance σ^2	Skewness $E\left[Log\left(\frac{c_{t+1}}{c_t}\right) - E\left[Log\left(\frac{c_{t+1}}{c_t}\right)\right]\right]^3$	Kurtosis $E\left[Log\left(\frac{c_{t+1}}{c_t}\right) - E\left[Log\left(\frac{c_{t+1}}{c_t}\right)\right]\right]^4$
Caribbean Region	2.45	0.0083	-0.19	0.58
Sub-Saharan Africa	0.90	0.0074	-0.21	1.78
Middle East & North Africa	1.60	0.0061	-0.07	1.13
Latin America	1.44	0.0035	-0.47	2.04
Europe and Central Asia	1.49	0.0030	-0.52	1.11
East Asia and Pacific	2.90	0.0018	-0.41	3.52
OECD	2.50	0.0006	-0.08	0.52

1/ The geometric Brownian motion is the prototypical process used in finance to model stock price movements.
2/ This is equivalent to say that instantaneous per capita consumption growth follows a generalized Wiener process.
3/ In large samples of normally distributed data, the skewness and kurtosis estimators are normally distributed with means 0 and 3 and variances $6/T$ and $24/T$, respectively (Stuart and Ord, 1987, Vol. 1).

Table 1.1: Consumption Path: International Comparison

Countries/Regions	Number of Countries	Population ('000, 1997)	Per Capita Consumption		
			Growth[1/] (%)	Standard Deviation[2/] (x 100)	Certainty-Equivalent Growth [3/] (%)
Barbados		265	1.51	7.46	0.40
Belize		217	0.48	9.92	-1 49
Dominica		74	2.18	5.69	1.54
Dominican Republic		7,968	2.91	6 83	1.98
Grenada		96	3 49	5.31	2.92
Guyana		749	2.77	17.13	-3.10
Haiti		7,492	-0.07	5 59	-0.69
Jamaica		2,554	1 07	8.61	-0.41
St. Kitts and Nevis		41	5.75	8.15	4.42
St Lucia		150	3.69	11.33	1.12
St. Vincent and the Grenadines		112	3.43	8.52	1.98
Trinidad and Tobago		1,278	2.18	8.17	0.85
Caribbean*	**12**	**20,995**	**2.45**	**8.56**	**0.79**
Argentina		35,672	1.48	5.75	0.82
Chile		14,622	3.01	10.10	0.97
Colombia		40,042	2.45	2.44	2.33
El Salvador		5,911	1.08	5.46	0.48
Honduras		5,939	0 68	3.55	0.43
México		93,909	1.75	3.60	1.49
Nicaragua		4,680	-0.67	7.71	-1 86
Paraguay		5,085	2.81	6.00	2.09
Uruguay		3,265	1.39	5.73	0.74
Venezuela		22,777	0.44	4.65	0.00
Latin America*	**10**	**231,904**	**1.44**	**5.50**	**0.75**
Sub-Saharan Africa*	**37**	**498,877**	**0.90**	**7.98**	**-0.58**
Middle-East & North Africa*	**7**	**207,460**	**1.60**	**7.08**	**0.37**
Europe and Central Asia (Non OECD)*	**6**	**291,422**	**1.49**	**4.93**	**0.89**
East Asia and Pacific*	**8**	**1,633,758**	**2.90**	**3.92**	**2.55**
France		58,208	2.45	1 38	2.41
Japan		126,091	4.05	2.53	3.93
United Kingdom		59,009	2.00	1.65	1.94
United States		271,542	2.00	1.49	1.95
OECD	**21**	**742,911**	**2.50**	**2.17**	**2.39**
Memo (Weighted average using 1997 population):					
Caribbean			1.55	7.47	0.43
Latin America			1.71	4.84	1.24
Sub-Saharan Africa			0.13	8.28	-1.24
Middle-East & North Africa			1.62	6.75	0.71
Europe and Central Asia			0.15	4.26	-0.21
East Asia and Pacific			4.63	5.26	4.07
OECD			2.59	1.94	2.52

* Unweighted average.

[1/] Refers to the expected instantaneous growth of per capita consumption defined as μ in Box 1.1.

[2/] Refers to the standard deviation (or volatility) of per capita consumption growth defined as σ in Box 1.1.

[3/] Refers to the certainty-consumption growth defined as μ_e in Box 1.2. We assume that $\rho = 4$ which is consistent with available empirical evidence.

Source: SIMA database (1960-97)

In the Caribbean region, the volatility of consumption undermines the welfare benefits of consumption growth. In terms of individual welfare, consumption volatility is very costly in the Caribbean region. Risk-adverse individuals prefer a smooth and stable consumption path to one which fluctuates, because their economic welfare depends positively on consumption growth but negatively on consumption volatility. Consequently, an individual would be willing to forfeit some percentages of consumption growth in order to eliminate the volatility of consumption and face a smooth consumption path, or what is referred to in Table 1.1 as the certainty-equivalent consumption growth. Specifically, a representative individual of the Caribbean region is willing to forego 1.66 percentage points of consumption growth on a sustainable basis – i.e. to accept an average consumption growth equivalent of 0.79 percent instead of 2.45 percent with a volatility of 0.0856 – in order to face a consumption path which does not fluctuate. In contrast, a representative individual of the Latin America region is willing to forego only 0.69 percentage point of consumption growth on a sustainable basis – i.e. to accept an average certainty-equivalent consumption growth of 0.75 percent instead of 1.44 percent with a volatility of 0.055. Furthermore, the low level of consumption volatility in OECD countries does not undermine the welfare benefits derived from consumption growth (Table 1.1). Although it is sometimes argued that international risk-sharing would decrease consumption volatility and hence increase individual welfare, this needs not be the case (Box 1.3).

Box 1.2: Defining and Measuring Certainty-Equivalent Consumption Growth

We assume that:

(i) individuals have time-separable expected utility function with constant risk-aversion preferences given by $u(c)=\frac{c^{1-\rho}-1}{1-\rho}$ where $\rho>0$ and $\rho\neq 1$ is the coefficient of relative risk aversion or $u(c)=Log c$ the limiting case when $\rho=1$;

(ii) per-capita consumption follows a geometric Brownian motion with drift represented by $\frac{dc}{c}=\mu\cdot dt+\sigma\cdot dZ$ and defined in Box 1.1;

(iii) the rate of time preference is $\beta>0$.

Per-capita consumption at any time t is given by $c_t=c_0\cdot\exp\left[\left(\mu-\frac{1}{2}\cdot\sigma^2\right)+\sigma\cdot\left[Z(t+1)-Z(t)\right]\right]$. Expected utility is $V(c_0,\mu,\sigma^2,\rho)=E_0\left[\int_0^\infty u(t)\cdot e^{-\beta t}\,dt\right]$ which can be rewritten $V(c,\mu,\sigma^2,\rho)=\frac{c_0^{1-\rho}}{1-\rho}\cdot\frac{1}{\beta+(\rho-1)\cdot\left(\mu-\frac{1}{2}\cdot\rho\cdot\sigma^2\right)}-\frac{1}{\beta\cdot(1-\rho)}$.

Note that the same expected utility is obtained when per-capita consumption follows the deterministic process represented by $\frac{dc}{c}=\left(\mu-\frac{1}{2}\cdot\rho\ \sigma^2\right)\cdot dt=\mu_e\cdot dt$ where $\mu_e=\mu-\frac{1}{2}\cdot\rho\cdot\sigma^2$. We then define μ_e as the certainty-equivalent consumption growth.

Box 1.3: Would International Risk-Sharing Increase Welfare?

Some studies claim that international risk-sharing would decrease consumption volatility and hence increase country-specific welfare (See for example, De Ferranti et al., 2000, pp. 62-63). However, such analyses do not take into account the impact of international risk-sharing on consumption growth. Although international risk-sharing decreases consumption volatility, leading to some welfare gains, international risk-sharing may also simultaneously lead to a decline in consumption growth for some countries, decreasing their welfare. As an extreme example, a country with a production growth of 5 percent and no volatility would not find it advantageous to share risks with another country which grows at 1 percent and is volatile.

In fact, most studies that seek to derive the benefits from international risk-sharing use as examples developed economies with comparable levels of consumption growth and volatility but asymmetric shocks (van Wincoop, 1999; Kraay and Ventura, 2001). However, when these conditions are not met, international risk-sharing does not systematically increase welfare.

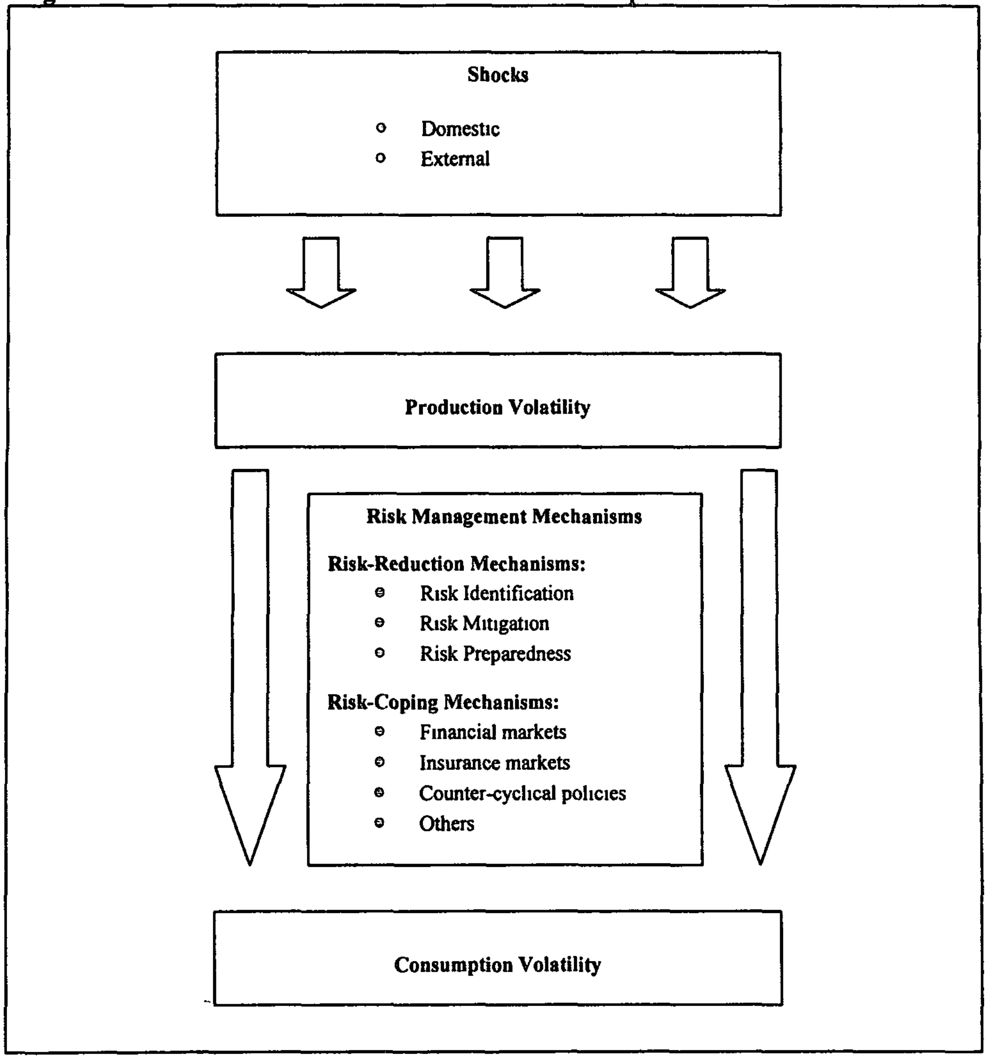
A.2. Determinants of Consumption Volatility[2]

A.2.1. A Theoretical Framework

The general equilibrium framework, arguably the most important result of economic theory to date, shows that under the assumption of complete markets (i.e. fully developed financial and insurance markets), individuals are able to trade risk so that fluctuations in income do not result in fluctuations in consumption (Debreu, 1959; Arrow and Hahn, 1971). In such a framework, individuals have recourse to well-developed domestic and international financial and insurance markets to alleviate the impact of production shocks on consumption so that the remaining shocks to consumption are the global shocks which are not diversifiable away even internationally. However, in reality, fluctuations in income do translate into fluctuations in consumption if risk management mechanisms are not fully developed or effective (Chapter 2 provides a conceptual framework for risk management). Within this context, the volatility of consumption comes from production shocks which are translated into consumption shocks mostly because of inefficient risk-management mechanisms (Figure 1.1). The shocks to the production process may be domestic or external in origin. Domestic shocks can result from inadequate macroeconomic policies or from destabilizing events like civil unrest, armed insurrections or civil wars. External shocks can be in the form of international conflicts, natural hazards, terms of trade shocks or global shocks from worldwide booms and recessions.

[2] The flagship report "Securing our Future" (World Bank, 2000) shows that terms of trade shocks and macroeconomic policies are important determinants of volatility. However, terms of trade shocks and macroeconomic policies need not have a direct impact on consumption volatility in the presence of well-developed financial and insurance markets that allow households to insure consumption against such shocks. We excluded these types of shocks in this section because they are not proximate determinants of consumption volatility. Indeed, these shocks (like catastrophic events) have an impact on production and affect consumption only to the extent that financial markets are not complete.

Figure 1.1: The Links between Production and Consumption Volatilities

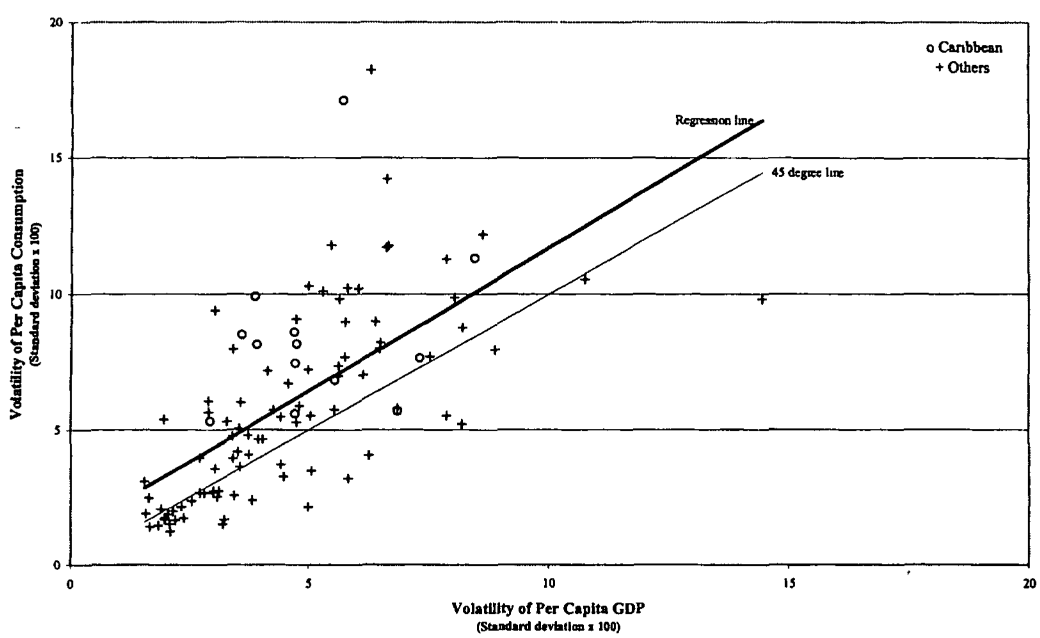


A.2.2. Empirical Evidence

This section attempts to draw some inferences from the theoretical framework developed in the preceding section and to test them empirically.[3]

A first inference from the theoretical framework is that consumption volatility can be expected to be larger in countries with high income volatility. This phenomenon is illustrated in Graph 1.1 which plots the volatility of per capita consumption against the volatility of per capita income. However, what is surprising is that countries typically lie above the 45-degree line where the volatility of consumption is higher than that of income (this is the case in 67 of the 102 countries and in only 1 of the 12 Caribbean countries considered).[4] This seems to indicate that the risk-management mechanisms seem to amplify shocks rather than help absorb them. Production volatility by itself accounts for about 40 percent of the observed variation in consumption volatility across countries, which implies that it is indeed a main factor which helps to explain the volatility of consumption (Table 1.2).

Graph 1.1: Consumption Volatility and Income Volatility



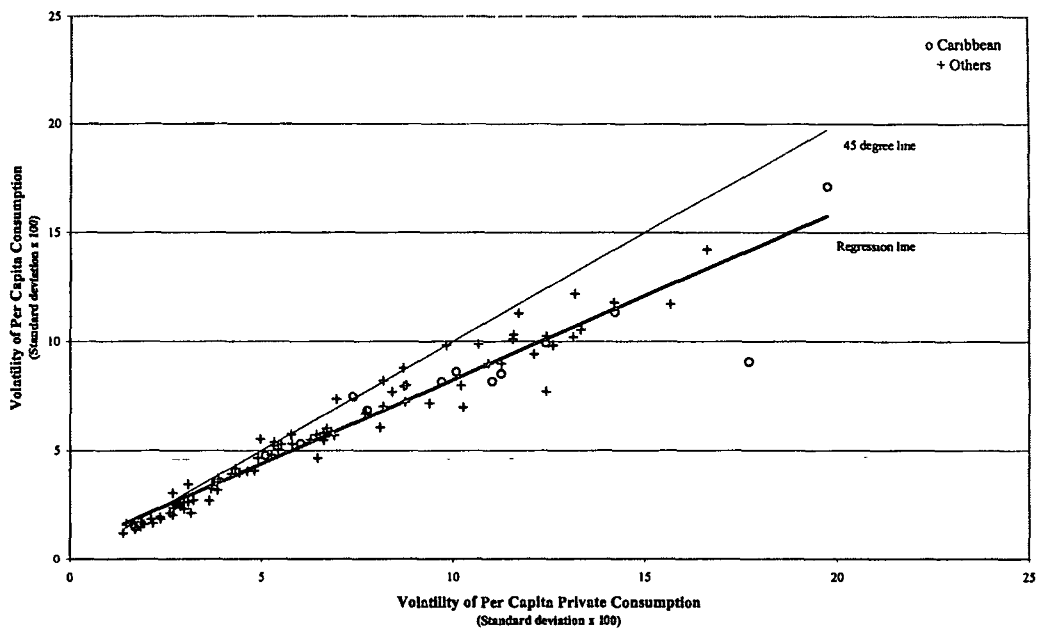
Source: SIMA database (102 countries included).

[3] De Ferranti, 2000 and World Bank 2000 (a) present a series of stylized facts that help understand consumption and production volatilities.

[4] In autarky, consumption volatility and production volatility should be equal while consumption volatility should be less than production volatility under international risk-sharing.

A second inference is that if counter-cyclical policies are effective in reducing consumption volatility, the volatility of private consumption can be expected to be higher than that of total consumption. Graph 1.2 plots the volatility of per capita consumption against the volatility of per capita private consumption. Countries typically lie below the 45-degree line where the volatility of total consumption is lower than that of private consumption. Applicable to all regions and almost all countries, this observation indicates that governments indeed play some positive role in reducing total consumption volatility or in smoothing total consumption by providing more public goods during periods of low private consumption. In the Caribbean region, the volatility of total consumption is 8.6 percent, while that of private consumption is 10.6 percent. However, the countercyclical role of public consumption varies across countries. For example, public consumption is very effective in reducing private consumption volatility in Guyana and Trinidad and Tobago, while in Barbados and the Dominican Republic public consumption does not exhibit the same degree of smoothing.

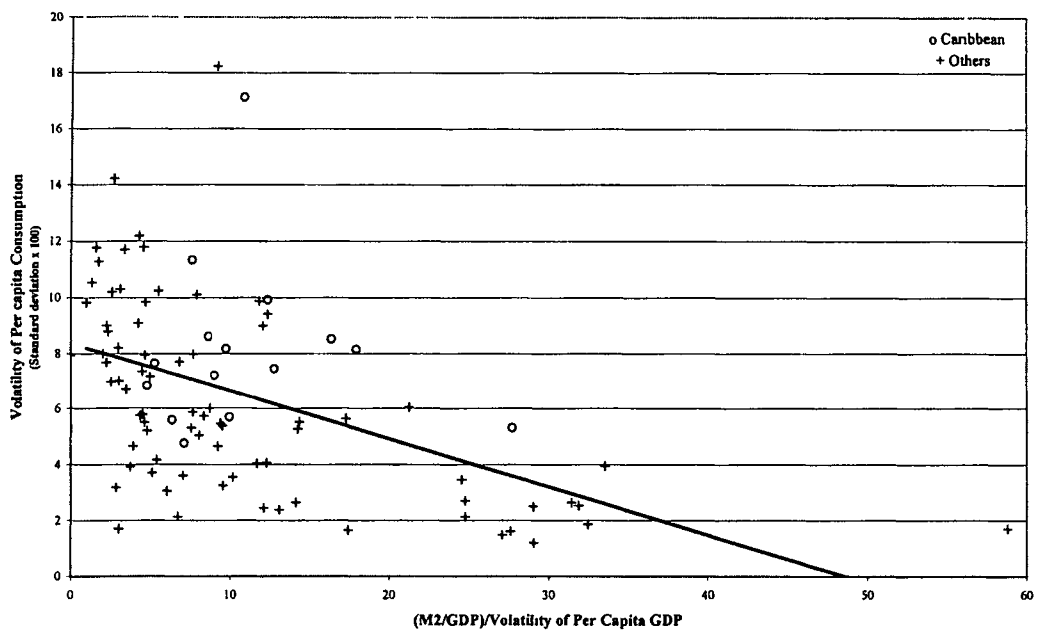
Graph 1.2: Consumption Volatility and Private Consumption Volatility



Source: SIMA database (98 countries included).

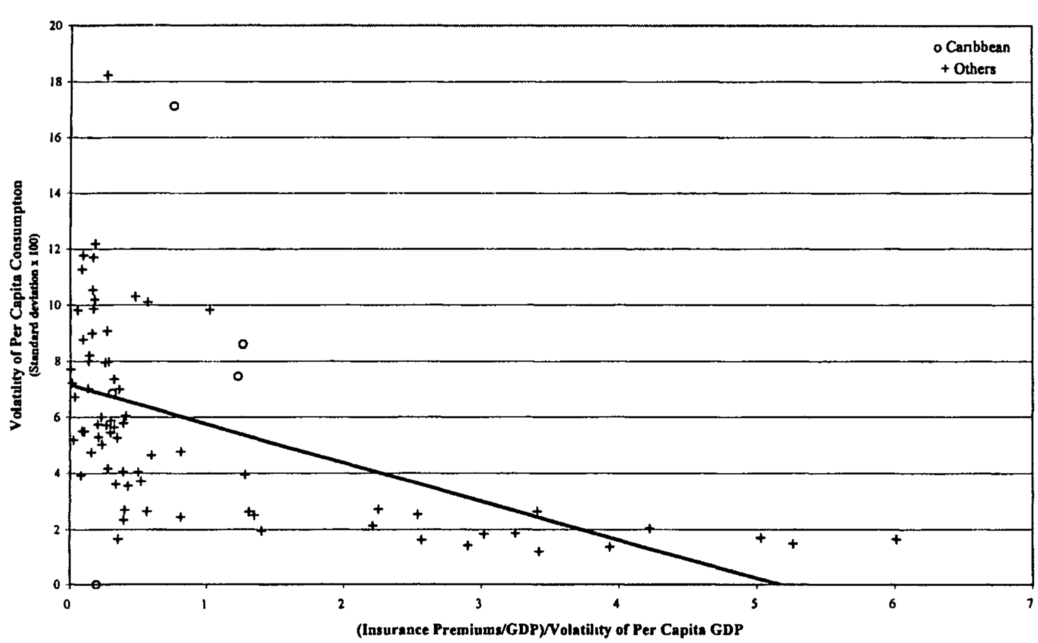
A third testable inference is that on average consumption volatility can be expected to be higher in countries with less developed financial and insurance risk management mechanisms. Financial depth (monetary aggregate M2 divided by GDP) divided by the volatility of output is used as a proxy for the presence of financial risk coping mechanisms. This variable -- which increases as financial depth increases or production volatility decreases -- is used as a proxy for the availability of financial instruments in the presence of volatile output. Insurance depth (insurance premiums divided by GDP) divided by the volatility of output is similarly used as a proxy for the presence of insurance risk coping mechanisms. Graphs 1.3 and 1.4 illustrate the fact that financial and insurance instruments are important instruments of consumption smoothing, allowing individuals to transfer outputs across space and time. Each of these two variables by itself accounts for about one-fourth of the observed variation in volatility across countries, which also indicates that they are key determinants of consumption volatility (Table 1.2).

Graph 1.3: Consumption Volatility and Risk-Coping Financial Mechanism



Source. SIMA database (91 countries included)

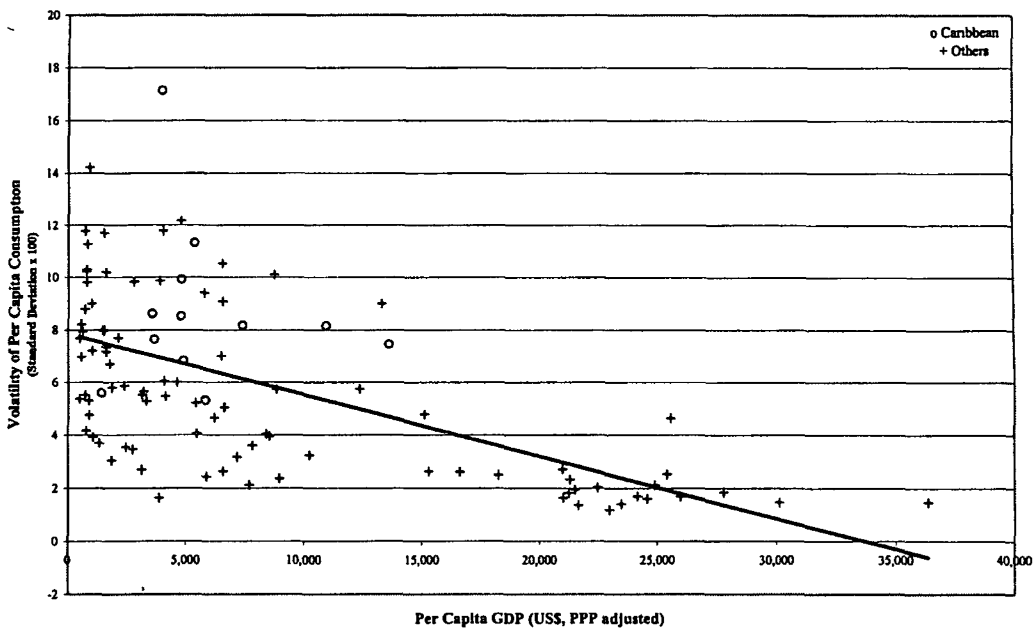
Graph 1.4: Consumption Volatility and Risk-Coping Insurance Mechanism



Source. SIMA database (77 countries included)

A fourth inference from the theoretical framework is that consumption volatility can be expected to be smaller in developed countries with developed risk-reduction mechanisms (risk identification, risk mitigation and risk preparedness) (see Chapter 2). Graph 1.5 illustrates the inverse relationship between consumption volatility and level of economic development. The level of economic development by itself accounts for about one-third of the observed variation in consumption volatility across countries, which implies that it is also an important factor in explaining the volatility of consumption (Table 1.2).

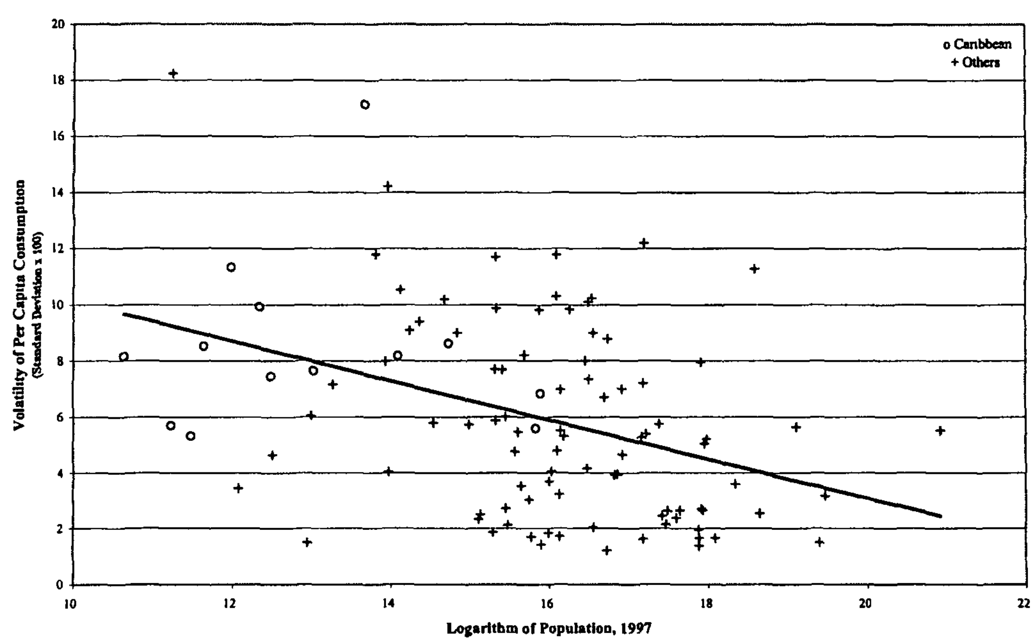
Graph 1.5: Consumption Volatility and Per Capita Income



Source: SIMA database (100 countries included).

A fifth inference is that smaller economies are expected to suffer from higher consumption volatility than larger economies. Smaller economies are less able to take advantage of economies of scale because their production is not diversified. As in the case of the Caribbean region, their size makes them vulnerable to the impact of hurricanes and other natural disasters. Also, large industrial economies may not suffer from significant output losses because regional or asymmetric shocks from disasters may be absorbed by economic activities in other regions and transfers across regions. This fact is summarized in Graph 1.6 which plots the volatility of per capita consumption against country size (as measured by the logarithm of the population). Country size by itself accounts for about one-third of the observed variation in consumption volatility across countries, which implies that it is also a main factor which explains the volatility of consumption (Table 1.2).

Graph 1.6: Consumption Volatility and Country Size



Source: SIMA database (102 countries included).

The above variables are tested empirically by regressing consumption variability on a constant, proxies of financial and insurance risk management mechanisms, per capita GDP and (the logarithm of) population (Regression 6 in Table 1.2). With the exception of the insurance mechanism proxy, the coefficients of each explanatory variable have the expected signs. However, the coefficients of the financial and insurance mechanism proxies and of per capita GDP are not statistically significant due mostly to multicollineary between them. When the insurance consumption mechanism proxy and per capita GDP are dropped, the coefficients of the remaining explanatory variables have all the expected signs and are statistically significant (Regression 7). The remaining three explanatory variables explain half of the volatility of consumption. When both the insurance and financial mechanism proxies are dropped, the coefficients of the remaining explanatory variables also have the expected signs and are statistically significant (Regression 8). The remaining three explanatory variables explain about 60 percent of consumption volatility.

Table 1.2: Determinants of Consumption Volatility
Dependent Variable: Volatility of Per Capita Consumption[1/]

Exogenous Variables	Regressions							
	1	2	3	4	5	6	7	8
Constant	1.16 (1 82)	8.37 (17 33)	7.27 (16 82)	7.85 (20.79)	17.26 (6 60)	13.24 (4.68)	13 88 (6.15)	12.22 (6 35)
Production Volatility[2/]	1.06 (8 44)					0.66 (4 76)	0.69 (4.94)	0.72 (6.46)
Financial Depth/Production Volatility[3/]		-0.17 (-5 22)				-0 07 (-1.65)	-0 09 (-2.89)	
Insurance Depth/Production Volatility[4/]			-1.42 (-5.52)			0.61 (1.19)		
Per Capita GDP				-0.0002 (-7.37)		-0.0001 (-1.76)		-0.0001 (-4.67)
Log (Population)[5/]					-0.71 (-4.32)	-0.56 (-3.35)	-0.62 (-4.92)	-0.54 (-4.81)
Number of countries	101	90	76	100	102	66	91	100
R-squared	0.42	0 24	0.29	0 36	0.16	0 61	0.53	0.62
Adjusted R-squared	0.41	0.23	0.28	0.35	0.15	0.58	0.51	0 61
DW	1.75	2.13	1.59	2.10	1 38	2 07	2 31	2.07

[1/] Standard Deviation of Consumption Per Capita.
[2/] Standard Deviation of Production Per Capita.
[3/] Ratio of M2/GDP to production volatility.
[4/] Ratio of insurance premiums/GDP to production volatility.
[5/] Logarithm of 1997 population
Note t-statistics given in parentheses.
Source SIMA database of the World Bank.

B. Effects of Natural Disasters on Macroeconomic Variables

B.1. A Theoretical Framework[5]

This section develops a theoretical framework to assess the effects of natural disasters on individual and household welfare.

B.1.1. Effects of Natural Disasters on Household Welfare

The impact of natural disasters on household welfare may be classified into three categories: physical integrity, assets and income. Individual integrity is vulnerable to the consequences of natural disasters, inasmuch as immediate fatalities, debilitating injuries and health epidemics compromise the quality of life. The loss of lives permanently deprives households of productive members, orphans minor dependents and leaves a legacy of psychological and financial burdens. Additionally, incapacitating injuries limit one's ability to carry out full-scale productive functions and can mean prolonged hospitalization or rehabilitation and a significant decrease in a household's earning power. In the aftermath of geological or weather-related hazards, ruptured or overflowing sewage systems can disrupt or contaminate water supply to large areas, as well as increase the risk of water-borne diseases. Subsiding floods leave in their wake stagnant pools that quickly become a breeding ground for malaria-transmitting mosquitoes. In sum, overcrowded living quarters, inadequate disposal of waste and the environmental impact of disasters combine to incubate bacteria, viruses and other parasites that threaten public health and economic welfare.

Disasters lead to the loss of tools, dwellings and other income-generating fixed or liquid assets. Houses are particularly vulnerable to the damaging impact of earthquakes, high winds, volcanic eruptions, landslides and floods. Shops, factories and markets are not immune to the

[5] This Section draws on Celine Charveriat, *Natural Disasters in Latin America and the Caribbean: An Overview of Risk*. October 2000. Inter-American Development Bank. Working Paper #434.

consequences of catastrophic occurrences. The loss of income from flooded arable land, damaged food crops and reduced agricultural production, may be temporary or permanent. Farmers can neither cultivate water-logged fields nor can flooded farms yield their expected produce. Flash floods and storm surges from hurricanes lead to increased salinity and decreased output of farmland. The loss of such perennial crops as coffee and bananas has long-term effects on a household's ability to replenish lost income or generate new sources of financial sustenance. For example, after Hurricane Mitch in 1998, the banana industry in Honduras was not expected to recuperate its lost volume of production until 2002.

The impact of natural disasters on household welfare depends primarily on the extent of the damage sustained by income-generating assets and on the period of disruption of flows of goods and services (Table 1.3). Invariably, the impact is more intense in the immediate aftermath of a disaster and may be absorbed relatively quickly afterward, as was the case in Honduras after Hurricane Mitch.

Table 1.3: Effects of Natural Disasters on Household Welfare

Welfare Indicators	**Expected Post-Disaster Effects**
Physical Integrity	Fatalities, incapacitating injuries, epidemics, poor sanitation, inadequate shelter, impaired public safety and dislodging of wildlife from natural habitat.
Assets	Decrease in agricultural production, small business operations, access to roadways and productive activities.
Income	Inability to work, loss of cash crops and decreased food crops will mean reduced household earnings, decrease in food consumption and inability to purchase previously affordable basic goods and services.

B.1.2. Effects of Natural Disasters on Macroeconomic Variables

This section develops a theoretical framework to assess the effects of natural disasters at the aggregate level (Table 1.4).

Natural disasters have direct effects on the stock of human and physical capital which, in turn, affects production, consumption, investment and the current account of the balance of payments. Natural hazards produce direct damages comprising total or partial destruction of housing, buildings, installations, machinery, equipment, means of transportation, storage and furniture, as well as damages to cropland, irrigation works and dams and the destruction of crops ready for harvesting. Calculating **direct damages** is difficult, especially in countries where assets are not registered. Moreover, some damages to the environment (for instance, erosion or total sedimentation that makes the land unsuitable for cultivation) as well as negative effects on human capital are difficult to assess.

Natural disasters also cause **indirect damages**, which refer to the loss of production of goods and services resulting from the destruction of the means of production. Indirect damages include loss of future harvests as a result of flooding of farmland or loss of perennial crops, loss of industrial output as a result of damages to factories or lack of inputs and increased transport costs due to destruction of roads or other transport infrastructure. Indirect damages continue to occur until reconstruction is completed and the entire production capacity is restored, which can take several years.

Natural disasters immediately reduce the amount of physical capital in an economy, which in turn reduces output. Consequently, natural hazards have an immediate negative impact on growth. Effects on economic sectors (agriculture, industry and services) depend on the nature of the catastrophic event. A hurricane may primarily affect agricultural production while an earthquake may destroy the industrial productive capacities. The disruption to the production process including transportation infrastructure translates into a decline in exports and imports increase as part of the reconstruction process. The decline in exports and the increase in imports lead to a deterioration of net exports – which usually translate into a deterioration of the balance of payments. The impacts of natural disasters on investment depend on the reconstruction effort. However, risk-coping measures (see Chapter 2) are likely to be insufficient in the short-term in restoring the investment to pre-shock level. Consequently, natural disasters can be expected to have an immediate negative effect on total investment. It can also be expected that private investments would decline more than public investment as the public sector may have more capacity to restore its investment capacity. Also, the Government can be expected to implement countercyclical policies leading to higher fiscal deficits. Higher fiscal deficit originates from a decline in tax revenues linked to the decline in production and from an increase in public expenditures to finance reconstruction. Inflation can be expected to increase in the aftermath of a catastrophic event due to the disruption of the production and distribution processes and money creation to finance the reconstruction effort. It can be expected that the negative impact on production translates into a decrease in both private and public consumption although ex-post international financing together with the implementation of countercyclical fiscal policy may allow the public sector to be in a better position to maintain public consumption at or above pre-shock level. In fact, public consumption could theoretically increase in the aftermath of a catastrophic event as more public sector workers are hired to assist with the reconstruction effort. Long-term impacts are more difficult to predict because they depend closely on the mode and timing of the reconstruction effort. If lost capital is not replaced, there might be long-term negative effects.

Table 1.4: Effects of Natural Disasters on Macroeconomic Variables

Macroeconomic Indicators	Expected Post-Disaster Effect
Physical Stock	Destruction of capital stock followed by reconstruction.
1. Production (2+3+4)	Decrease followed by increase.
1.1 Agriculture	Significant drop in production (if hurricane, flood or drought).
1.2 Industry	Decrease due to disruption of transportation, reduced capital stock and production capacities.
1.3 Service	Decrease due to disruption of transportation and payment system.
2. Consumption	Decrease due to decline in production
2.1 Private	Decrease due to decline in production.
2.2 Public	Decrease somewhat mitigated by ex-post international financing and counter-cyclical fiscal policy.
3. Investment	Decrease in investments in the aftermath of the disaster.
4. Net Exports of Goods and Services	Decrease in exports due to disruption of production process including transportation infrastructure. Increase in imports as part of the reconstruction process.
Public Finances	Increase in fiscal deficit due to a decline in tax revenues linked to the decline in production and the increase in public expenditures for reconstruction.
Inflation Rate	Increase caused by the disruption of production and distribution and increasing transportation costs.

Source. Adapted from Albala-Betrand (1993) and Downing, Holstoorn and Tol (1999). As reported in Charveriat (2000), Table 1.2 p. 16.

B.2. Empirical Evidence

B.2.1 Catastrophic Events: Occurrence, Impacts and Evolution

Natural hazards have a devastating impact on Caribbean economies (Box 1.6). For the period 1970-99, the Caribbean region averaged 11.9 catastrophic events a year (Table 1.5). Cumulative damages from catastrophic events in the region for the period 1970-99 amounted to US$8.5 billion corresponding to a country average of US$605.3 million (12 percent of GDP), equivalent to US$20.18 million per annum on average. Five out of the thirteen countries for which data are available recorded cumulative economic losses above 25 percent of GDP during the period. Montserrat's staggering economic loss of 899 percent is an extreme example of the devastating impact that a natural disaster can inflict on a Caribbean island (Box 1.5). Between 1979 and 1995, the Dominican Republic, Jamaica, Montserrat, St. Kitts, Antigua and Barbuda suffered heavy losses in human lives, housing stock, territorial infrastructure and economic growth indicators (Box 1.6). Box 1.7 provides a more detailed analysis of the impacts of Hurricane Georges on the Dominican Republic in September 1998 as well as the policy responses.

Box 1.4: Definition of Selected Natural Hazards

Geological Hazards

An **earthquake** is a sudden tremor of the earth's substrata that may be caused by the movement of large masses of rocks or tectonic plates along fault lines in mountain ranges or mid-oceanic ridges.

A **tsunami** is a wave train or series of waves generated in a body of water by an impulsive disturbance (such as earthquakes) that vertically displaces gigantic water columns. Tsunamis may reach a maximum run-up or above-sea-level height of 10, 20, or even 30 meters.

Slides are a downward slope movement of soil, rock, mud or snow because of gravity. One of the most common sources of slides is prolonged torrential downpours of rain or the accumulation of heavy snow. Mass displacement of large mud, snow or rocks can also be triggered by seismic waves.

Lahars are **mudflows** that are caused by the melting of the icecap by lava from a volcano or the downhill run-off of volcanic ash because of heavy rainfall.

A **volcanic eruption** is the process whereby molten lava, fragmented rocks or gases are released on to the earth's surface through a deep crater, vent or fissure.

Meteorological Hazards

Hurricanes and **Tropical Storms** are large-scale, closed circulation system in the atmosphere with low barometric pressure and strong winds that rotate counter clockwise in the northern hemisphere and clockwise in the southern hemisphere.

Floods are a temporary inundation of normally dry land by overflowing lakes or rivers, precipitation, storm surges, tsunami, waves, mudflow, lahar. They may also be caused by the failure of water retaining structures, groundwater seepage and water-back up in sewer systems.

Drought is a lack or insufficiency of rain for an extended period that can cause a considerable hydrological imbalance and, consequently, water shortage, crop damage, stream-flow reduction and depletion of groundwater and soil moisture. It occurs when, for a considerable period, evaporation and transpiration (the release of underground water into the atmosphere through vegetation) exceeds precipitation.

Forest fires are uncontrolled fires whose flames can consume trees and other vegetation of more than 6 feet (1.8m) in height. These often reach the proportions of a major conflagration and are sometimes begun by combustion and heat from surface and ground fires.

Source: IDNDR (1992); Bell (1999); Swiss Re (1988, p. 16); Pidwirny (1999); and Encyclopedia Britannica [http://www.Britannica.com].

Table 1.5: Disaster Exposure Indicators, Caribbean Region (1970-1999)

Country	Disaster Occurrence			Disaster–Related Fatalities		Economic Losses	
	Number of Catastrophic Events	Occurrence per year	Occurrence per km2	Fatalities	Fatalities (per 1000 inhabitants, 1995)	Amount (US$ million, 1998)	Percentage of GDP (Percentage, 1995)
Antigua & Barbuda	7	0.2	17.5	7	0.10	105.7	18.1
Bahamas	4	0.1	0.4	5	0.02	290.4	9.5
Barbados	5	0.2	12.5	3	0.01	148.4	6.3
Cuba	35	1.2	0.3	181	0.02	578.0	N/A
Dominica	7	0.2	8.8	43	0.60	133.4	55.0
Dominican Republic	17	0.6	0.4	1839	0.20	2,657.2	17.3
Grenada	4	0.1	13.3	0	0.00	30.1	9.5
Haiti	31	1.0	1.1	2031	0.30	288.7	7.3
Jamaica	19	0.6	2.6	271	0.10	1,988.1	29.3
St. Kitts & Nevis	7	0.2	17.5	6	0.20	312.5	116.5
St. Lucia	8	0.3	13.3	54	0.30	1,554.6	272.3
St. Vincent	9	0.3	22.5	5	0.04	47.0	16.5
Trinidad & Tobago	8	0.3	1.6	9	0.01	16.7	0.3
Montserrat[1]	5	0.2	50.0	43	3.40	323.7	899.0
Average	**11.9**	**0.4**	**11.6**	**321**	**0.40**	**605.3**	**112.0**
Memo:							
Central America	**33.6**	**1.1**	**0.3**	**9,184**	**1.10**	**3,868.0**	**60.6**
Latin America	**39.8**	**4.5**	**0.6**	**13,356**	**0.50**	**4,879.0**	**9.6**

[1/] GDP, 97 est., CIA World Fact Book.
N/A= Not available.
Source: EM-DAT; World Bank Development Indicators. Reported in Charvériat (2000, p.38)

Box 1.5: Impact of a Volcano on a Caribbean Island: The Case of Montserrat, UK

The Caribbean island of Montserrat, whose territory is 0.6 times the size of Washington DC, and has 12,853 inhabitants, constitutes an extreme example of the kind of impact that disasters can have on a small, undiversified economy. In 1996, 81 percent of the island's economic activities was associated with the tourism industry. In 1989, Hurricane Hugo caused an estimated US$240 million in damages and left a loss-to-output ratio of more than 600 percent.[1] The hurricane also damaged or destroyed 98 percent of the housing stock. In 1995, while the island was still recovering from Hugo (with growth rates between 0 and 2 percent in 1992, 1993 and 1994), the Soufriere Hills Volcano became active again after being dormant for 350 years, causing 32 fatalities and the evacuation of 70 percent of the population. Volcanic activity, which peaked in 1996-97 with several violent eruptions, subsided by March 1998, leaving much of the island uninhabitable and unsuitable for agriculture. The UK government has committed about US$100 million (equivalent to 300 percent of the island's GDP) to reconstruction. Despite this massive assistance and the boom generated in the construction sector, GDP declined by 18.5 percent in 1997 real terms and declined again in 1998.

[1] Calculation using 1996 GDP, CIA World Factbook
Source: CIA World Factbook 1999; DFID, 1999, pp. 60-61; Crowards, 1999, p. 18) in Celine Charveriat 2000

Box 1.6: Impact of Hurricanes on Caribbean Islands

A few examples illustrate the impacts of hurricanes on the Caribbean region.

In 1979, the Dominican Republic was hit by Hurricanes David and Frederick in a span of five days. Two thousand people died, 100,000 families were left homeless, and material damage across all sectors was estimated at one-third of 1979 GNP. Nearly 100,000 houses were destroyed, 37 percent of agricultural output was lost, and 85 percent of schools were damaged. Indirect effects included increases in fiscal deficit, and setbacks in health and education services.

The direct effects of Hurricane Gilbert on Jamaica in 1988 amounted to US$956 million, with nearly half from losses in agriculture, tourism and industry, 30 percent in housing, and 20 percent in economic infrastructure. Economic projections had to be adjusted dramatically, based on expected losses in export earnings of US$130 million, and lost tourism earnings of over US$100 million. Instead of a forecasted GDP growth of 5 percent, a decline of 1.8 percent was experienced. Other changes induced by the disaster were: increases in inflation (30 percent), government expenditures (US$220 million), and the public sector deficit (from 2.8 percent to 10.6 percent of GDP).

In September 1989, Hurricane Hugo's most severe damage was inflicted on Montserrat, leaving 10 fatalities, and a total damage estimate of US$240 million. Of the 98 percent of housing damaged by the storm, 50 percent was severely damaged and 20 percent totally destroyed. The port's concrete jetty was destroyed and debris littered all island roads. The three main hotels were put out of business for at least four months. Agricultural crops were destroyed, and the fishing sector lost boats, buildings and ports. The total damage exceeded five years of GDP.

In August and September 1995 Hurricanes Luis and Marilyn hit the Leeward Islands with direct damage estimated at US$149 million in St. Kitts, US$254 million in Antigua/Barbuda and some US$175 million in estimated rehabilitation costs in Dominica.[1] These hurricanes caused widespread impacts over public, social and private economic sectors.

[1]/ These costs are different from those reported in Table 1.5 We were unable to reconcile these differences.

Source. CARICOM Working Party, 1996, pp. 6-7.

Box 1.7: Impact of Hurricane Georges: The Case of the Dominican Republic

Hurricane Georges passed over the Dominican Republic in September 1998 as a category 3 hurricane with winds reaching 130 miles per hour. The eye of the hurricane entered the southeastern portion of the country in the morning, traversed the country at approximately 6 mph on a northwest path and arrived at the border with Haiti in the evening, downgraded to category 1. The destructive winds destroyed housing, agricultural and industrial infrastructure, uprooted trees and destroyed crops, mainly in the eastern part of the country. The heavy rain was centered in the southern and southwestern areas of the country and led to floods and rivers overflowing with water and mud, which destroyed bridges, homes, and household and farming equipment; damaged roads, schools, health clinics and water supply systems; and washed away crops, including sugarcane, bananas, yucca, coffee and vegetables. Because of its diameter, the hurricane affected at least 70 percent of the country, equivalent to 34,000 square kilometers. The areas most affected were the eastern and southern portions of the country, including some important urban areas such as La Romana, San Pedro de Macoris, Santo Domingo and San Juan de la Maguana. Some of the principal tourist enclaves in the southeast were badly damaged, as well as critical agricultural zones, such as the fertile San Juan valley and Cibao valley. The death toll stood at 235.

Economic and Social Impact

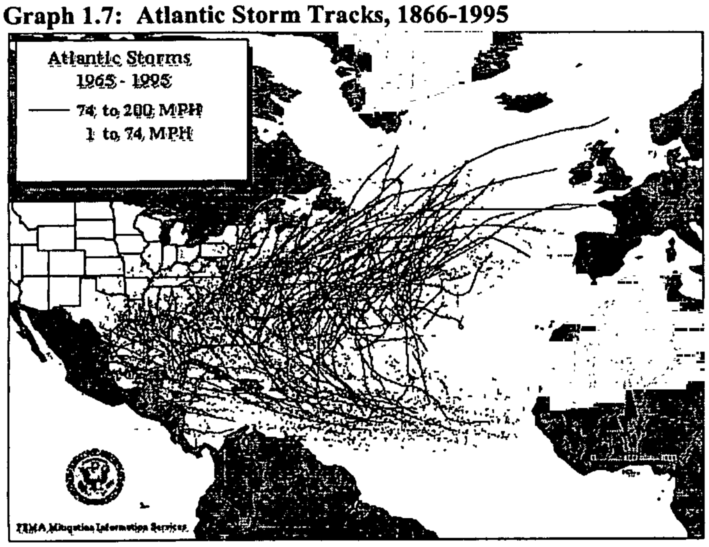
A team from the Economic Commission for Latin America and the Caribbean (CEPAL) visited the Dominican Republic in the second half of October and estimated the total cost of direct damages at US$1.3 billion (8 percent of GDP). While the adverse impact of the hurricane on GDP growth and inflation was limited, the economic recovery led to a temporary widening of the fiscal and external current account deficits, largely reflecting increased spending on (mostly imported) basic needs and reconstruction materials.

- **Agriculture**: The most important sector of the economy, agriculture accounts for 16 percent of GDP. It sustained the greatest damage, from the winds that uprooted trees and plants and destroyed infrastructure, and the rains that caused the rivers, particularly in the south/southwest regions, to overflow, flood fields and destroy cultivated land. One third of all cultivated land was affected. The crops grown for internal consumption were the most affected, particularly bananas and corn. Total damages in the sector, including livestock and fisheries, were estimated at US$527 million.
- **Transport**: The heavy rains caused serious damage to highways, roads and bridges. 20 percent of highways were affected, and 40 percent of local roads. 112 bridges were damaged, 55 of them destroyed. Total damages in the sector, including ports and airports, were estimated at US$292 million.
- **Housing**: The wind destroyed roofs, windows and external installations, and the rains flooded many homes. The most affected provinces have some of the highest concentrations of poor in the country: Santo Domingo, Monsenor Nouel, San Juan de la Maguana and San Pedro de Macoris. A total of 171,000 of houses, or 10 percent of the total, were affected, while 49,000 houses, or 3 percent of the total, were completely destroyed. Total damages were estimated at US$232 million.
- **Tourism**: The greatest damages were sustained in La Romana, La Altagracia and Juan Dolio. A total of 6,000 rooms were affected, at a estimated cost of US$149 million.
- **Electricity:** Transmission and distribution networks sustained the greatest damages, primarily in the eastern part of the country. Total damages were estimated at US$46 million.
- **Education**: 1,334 schools (28 percent of the total number of schools) were affected by the hurricane, of which 203 (4 percent of the total) were completely destroyed. As 443 of the largest schools were used as refuges for the homeless, the school year started several weeks late for close to 100,000 students. Total damages in the sector, which includes sports and recreational facilities, were estimated at US$69 million.
- **Health:** Damages in physical infrastructure were moderate - US$2 million in buildings and US$4 million in furniture and equipment; the regions most affected were Santo Domingo, La Altagracia, San Pedro de Macoris and La Romana. The indirect cost of attending to emergency needs, estimated at US$17 million, has made the greatest impact on the sector, as the lack of running water, food and medicine and accumulation of solid wastes resulting in water pollution, increased the incidence of infectious diseases.
- **Water & Sanitation:** As a consequence of flooding, the sector was adversely affected by damaged electricity lines, water mains and treatment plants, wells, access roads, distribution networks, windmills and emergency motors. Total damages were estimated at US$16.4 million.
- **Irrigation:** The torrential rains damaged canals and electrical infrastructure. Damages were not fully quantified because some areas were still inaccessible, but the estimated total so far was US$8.8 million.

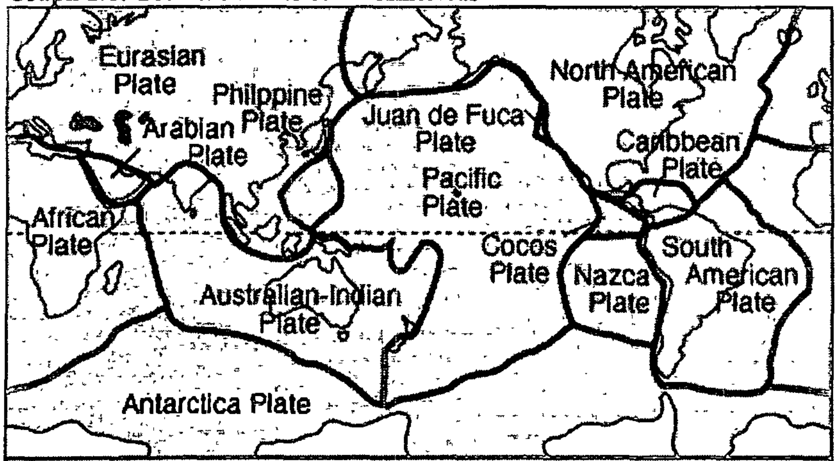
Source: Hurricane Georges Emergency Recovery Project, World Bank, 1998

Despite the common Caribbean Basin location, each country under study exhibits peculiarities that can affect the level of vulnerability to a specific type of catastrophic event. Although generally perceived as hurricane and flood-prone, the Caribbean region is located astride major tectonic plates and is vulnerable to seismic activities as well. Graph 1.7 shows the Atlantic storm tracks from 1866 to 1995, while Graph 1.8 shows the tectonic plates of the Americas. Based on historical data, the Caribbean region can expect 2.5 storms every year. Fortunately, severe hurricanes, defined as category 4 and 5, are less common. Category 4 hurricanes can be expected to occur every fourth year and category 5 hurricanes every fifth year. The northern and eastern islands are more exposed to hurricanes than the southern islands. The Dominican Republic, Haiti, Jamaica, Antigua, Montserrat, St. Kitts and Nevis are situated within the hurricane belt while Trinidad and Tobago lie to the southernmost end of the Caribbean chain and are considered only minimally vulnerable to hurricanes. In terms of seismic risk, the Caribbean region is located on five tectonic plates and counts 250 of the world's 500 most active volcanoes. However, there are significant differences in exposure. Jamaica and the Dominican Republic are located on the cusp of or close to five tectonic plates. Trinidad and Tobago also have a high earthquake risk. A few islands have volcano risk, most notably Montserrat, where recent eruptions have caused almost cataclysmic damage.

Graph 1.7: Atlantic Storm Tracks, 1866-1995



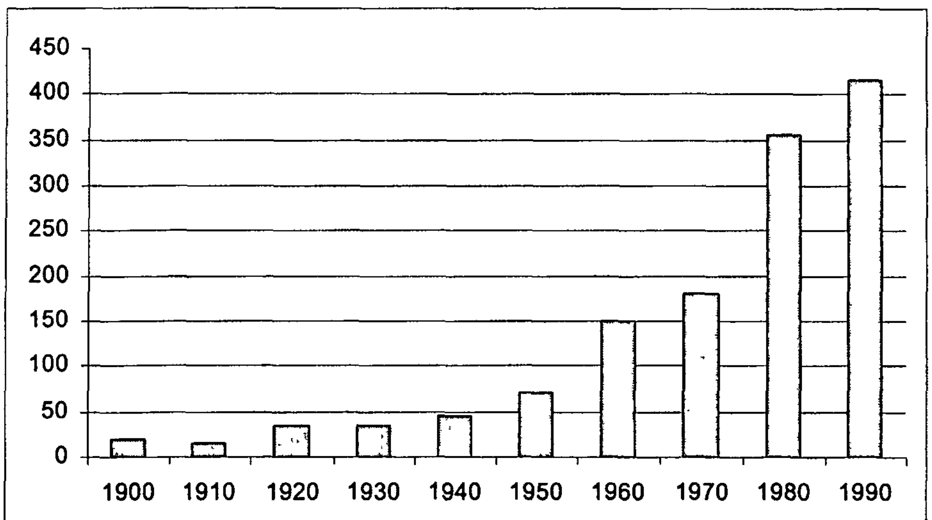
Graph 1.8: Tectonic Plates of the Americas



Major tectonic plates of the world.

The occurrence of natural hazards has increased in the last century and accelerated more recently. Throughout the twentieth century, the Latin America and Caribbean region was hit by 1,309 catastrophes (Graph 1.9). During the period 1970-99, Latin America and the Caribbean region were affected by 972 catastrophic events, 43 of which were classified as major disasters (Table 1.6).[6] Graphs 1.9 and 1.10 clearly reflect an increasing trend in the frequency of disasters over the past three decades.

Graph 1.9: Occurrence of Natural Disaster Events in Latin America and the Caribbean by Decade (1900-99)



Source : EM-DAT : The OFDA/CRED International Disaster Database- www cred be/emdat - Université Catholique de Louvain – Brussels - Belgium

[6] The impact of these events on macroeconomic variables is analyzed in the next section.

Graph 1.10: Annual Occurrence of Natural Disaster Events in Latin America and the Caribbean (1970-99)

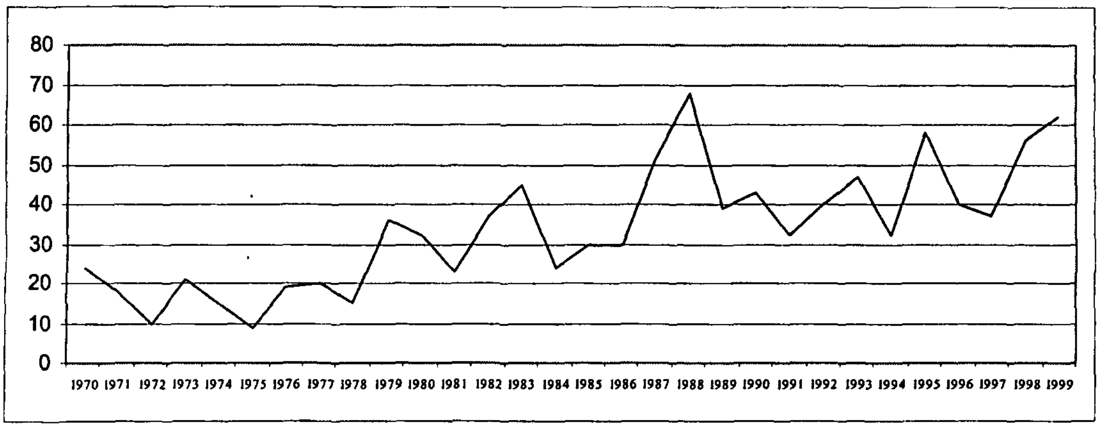


Table 1.6: Catastrophic Events and Losses: Latin America and the Caribbean, 1970-99.

Year	Country	Disaster Type	Deaths	Casualties	Damages (1998, US$ million)
1970	Brazil	Drought	N/A	10,000,000	0.4
1970	Peru	Earthquake	66,794	3,216,240	2,225.0
1972	Nicaragua	Earthquake	10,000	720,000	3,293.7
1973	Honduras	Landslide	2,800	0	N/A
1974	Honduras	Hurricane Fifi	8,000	730,000	1,784.6
1975	Brazil	Cold wave	70	600	1,817.0
1976	Guatemala	Earthquake	23,000	4,993,000	2,864.0
1978	Brazil	Drought	N/A	N/A	5,746.5
1979	Dominican Republic	Hurricanes David and Frederick	1,400	1,554,000	336.8
1983	Argentina	Flood	0	5,830,000	1,636.6
1983	Argentina	Flood	0	250,000	1,309.3
1983	Brazil	Drought	20	20,000,000	N/A
1983	Peru	Flood	364	700,000	1,618.3
1984	Brazil	Flood	17	159,600	1,568.9
1984	Brazil	Flood	10	120,400	1,568.9
1985	Argentina	Flood	12	206,000	1,969.4
1985	Chile	Earthquake	180	1,482.275	2,272.4
1985	Colombia	Volcano Nevado del Ruiz	21,800	12,700	1,515.0
1985	Mexico	Earthquake	8,776	130,204	6,059.8
1986	El Salvador	Earthquake	1,000	770,000	2,231.0
1987	Colombia	Earthquake	1,000	N/A	7,168.4
1987	Ecuador	Earthquake	4,000	227,000	1,003.6
1987	Ecuador	Tsunami	1,000	6,000	N/A
1988	Brazil	Flood	289	3,020,734	1,378.4
1988	Jamaica	Hurricane Gilbert	49	810,000	1,378.4
1988	Mexico	Hurricane Gilbert	240	100,000	1,860.9
1988	St. Lucia	Hurricane Gilbert	45	N/A	1,378.4
1989	Caribbean	Hurricane Hugo	42	33,790	4,706.2
1991	El Salvador	Earthquake	1,000	N/A	N/A
1993	Mexico	Tropical Storms Arlene & Beatriz	7	10,000	1,884.5
1994	Haiti	Tropical Storm Gordon	1,122	1,587,000	N/A
1995	US Virgin Islands	Hurricane Marilyn	8	10,000	1,604.6
1996	Mexico	Drought	0	N/A	1,247.1
1998	Argentina	El Niño, Flood	19	360,000	2,500.0
1998	Brazil	Drought	0	10,000,000	97.8
1998	Dominican Republic	Hurricane Georges	288	4,515,238	2,193.4
1998	Ecuador	El Niño, Flood	322	88,753	2,869.3
1998	Honduras	Hurricane Mitch	5,657	2,112,000	2,000.0
1998	Mexico	Flood	1,256	506,744	N/A
1998	Nicaragua	Hurricane Mitch	2,447	868,228	1,000.0
1998	Peru	Flood	340	580,750	1,200.0
1999	Colombia	Earthquake	1,186	1,205,933	2,837.9
1999	Venezuela	Flood/Debris Flows	30,000	483,635	1,957.2

N/A= Not available.

Note: Casualties include those requiring emergency food, water, shelter, sanitation and medical assistance. Individuals affected by disaster-related health epidemics are also included under the same rubric.

Source. Charvériat, 2000, p.30

B.2.2. Effects of Natural Disasters on Macroeconomic Variables

This section analyzes the impact of catastrophic events on macroeconomic variables for a sample of 16 countries (6 from the Caribbean region and 10 from Latin America).[7] The impact of catastrophic events on macroeconomic variables (production, public and private consumption, investment and external balance[8]) is estimated using dynamic panel data (DPD) models based on generalized methods of moments (GMM).[9] The catastrophic events considered are those described in Table 1.6. Catastrophic events are proxied by a variable (Cat) which takes the value of the costs of the damage (as percentage of GDP) in the year when the catastrophic events occur and zero otherwise.[10] Additionally, changes in (log) income Δy, (log) consumption Δc and (log) investment Δinv are modeled as autoregressive processes. After experimentation, two lags of the dependent variables appear to be sufficient to capture their auto-regressive components.

Table 1.7 reports the equations for production, total consumption and investment. In each equation, the catastrophe variable (Cat) has the sign expected from Table 1.4 and is statistically significant at conventional level of confidence. A catastrophic event leads to a fall in output, consumption and investment growth. However, the coefficient of the catastrophe variable shows that most of the impact is on investment growth (-0.49) while the impact on total consumption growth (-0.09) is more moderate. Simulations based on these regressions indicate a worsening of the current account in the aftermath of a catastrophic shock.

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[7] Countries included in the sample are Barbados, Bolivia, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Peru and Trinidad and Tobago. These countries were selected on the basis of the availability of information regarding the catastrophic events and the macroeconomic variables. Information on catastrophic events and damages are from Charveriat, 2000, p. 30 as reported in Table 1.6. Macroeconomic indicators (GDP, investment, and private and public consumption) for the period 1960-98 are from an extended version of the Penn World Tables (Summer and Heston, 1992).

[8] External balance is defined as the difference between production and the sum of consumption and investment.

[9] The GMM estimator is based on first differencing, and controls for the endogeneity of the lagged dependent variable and the potential endogeneity of the other explanatory variables (see Arellano, 1993; Arellano and Bond, 1998).

[10] Costs of damage are those reported in the last column of Table 1.6. In the few cases when damages are not reported we used the average of the other catastrophic events that occurred in the country or the average costs of the catastrophic events of all countries when information on other castastrophic damages was not available for this country. The results are robust to changes of specification. For example, we conducted the same regressions with a dummy variable which takes the value 1 in the year when a catastrophic event occurs (and 0 otherwise) and found very similar results.

Table 1.7: Impact of Catastrophic Events on Economic Variables
Dynamic Panel Data (GMM Estimator)
Country Specific Effects
Sample: 1963 - 1997
Total panel observations: 540

Variable	GDP Δy_t	Total Consumption Δc_t	Investment Δinv_t
Δy_{t-1}	0.86*** (3.26)	0.91*** (3.13)	1.32** (2 35)
Δy_{t-2}	0.15** (2.42)	0.27** (2.61)	0.49** (2.59)
Δinv_{t-1}			0.42** (2.14)
Δinv_{t-2}			-0.14 (1.08)
Δc_{t-1}		-0.10 (0.13)	
Cat_t	-0.49** (2.42)	-0.09*** (3.67)	-0.43** (1 98)
Diagnostic Statistics			
Wald test	16.65*** [0.001]	16.96*** [0.000]	39 23*** [0.000]
Sargan test	1.23 [0.968]	1.37 [0.125]	34.98 [0.285]
1st-order serial correlation	3.29** [0.040]	21.93*** [0.000]	2.74** [0.010]
2nd-order serial correlation	0.29 [0.767]	0.71 [0.477]	1.08 [0.281]

Notes:
a. Figures in parentheses ( ) are absolute t-ratios; figures in brackets [ ] are p-values. *, **, *** indicate that a coefficient is significant at the 10 percent, 5 percent and 1 percent level respectively.
b. The Wald test is for the joint significance of the regressors. Here, the explanatory variables are jointly significant at 1 percent of significance.
c. The Sargan test is of over-identifying restrictions, that is, for the validity of the set of instruments and is defined as Prob($J > \chi^2_p$), where p is the number of over-identifying instruments.
d. The tests for 1st and 2nd order of no serial correlation are asymptotically distributed as standard normal variables (see Arellano and Bond, 1991) The p-values report the probability of rejecting the null hypothesis of serial correlation, where the first differencing will induce (MA1) serial correlation if the time-varying component of the error term in levels is a serially uncorrelated disturbance. 1st and 2nd order of no serial correlation tests are related to the lags of the instruments (i.e. t_{-1} and t_{-2}), where the instruments are the lagged values of the explanatory variables and the lagged dependent variable (except the catastrophe dummy, which is an exogenous shock to the system)
e The GMM estimations were performed by using the DPD model developed by Arellano and Bond (1991) Ox version 3.00 (Windows) for PcGive (C) by J.A. Doornik (1994-2001).

Source: Estimated based on an extended version of the Penn World Tables 5.6 (Summer and Heston, 1992), and data on catastrophic events from Table 1.6.

Table 1.8 reports the equations for private and public consumption. In each equation again, the catastrophe variable (Cat) has the sign expected from Table 1.4 and is statistically significant at conventional level of confidence. Catastrophic events have a distinctive influence on private and public consumption growth. A catastrophic event leads to a fall in private consumption growth and a more moderate decline in public consumption growth. The absence of a larger decline in public consumption may result from public policies that aim at mitigating the impact of the event on overall consumption.

Table 1.8: Impact of Catastrophic Events on Public and Private Consumption
Dynamic Panel Data (GMM Estimator)
Country Specific Effects
Sample: 1963 – 1997
Total panel observations: 545

Variable	Private Consumption Δcp_t	Public Consumption Δcg_t
Δy_{t-1}	0 73*** (3 26)	0.85** (2.11)
Δy_{t-2}	0.22** (2.43)	
Δcp_{t-1}	-0.08 (0.44)	
Δcg_{t-1}		-0 16*** (4.95)
Cat_t	-0.22*** (4.93)	-0 05** (2.68)
Diagnostic Statistics		
Wald test	48.26*** [0.000]	15.78** [0.056]
Sargan test	14.14 [0 997]	7.97 [0.338]
1st-order serial correlation	16.75** [0 056]	19.95*** [0.001]
2nd-order serial correlation	0.52 [0.601]	0.91 [0 364]

Notes.

a Figures in parentheses ( ) are absolute t-ratios; figures in brackets [ ] are p-values *, **, *** indicate that a coefficient is significant at the 10 percent, 5 percent and 1 percent level respectively

b The **Wald** test is for the joint significance of the regressors.

c. The **Sargan** test is of over-identifying restrictions, that is, for the validity of the set of instruments and is defined as Prob($J > \chi^2_p$), where p is the number of over-identifying instruments

d The tests for 1st and 2nd order of no serial correlation are asymptotically distributed as standard normal variables (see Arellano and Bond, 1991). The p-values report the probability of rejecting the null hypothesis of serial correlation, where the first differencing will induce (MA1) serial correlation if the time-varying component of the error term in levels is a serially uncorrelated disturbance. 1st and 2nd order of no serial correlation tests are related to the lags of the instruments (i.e t_{-1} and t_{-2}), where the instruments are the lagged values of the explanatory variables and the lagged dependent variable (except the catastrophe dummy, which is an exogenous shock to the system).

e. The GMM estimations were performed by using the DPD model developed by Arellano and Bond (1991) Ox version 3 00 (Windows) for PcGive (C) by J.A Doornik (1994-2001).

Source: Estimated based on an extended version of the Penn World Tables 5 6 (Summer and Heston, 1992), and data on catastrophic events from Table 1 6.

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