Catastrophes and Macro-economic Risk Factors : An Empirical Study[1]

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Introduction

Do catastrophes affect macro-economic risk factors? What trends do past data on catastrophes suggest? Do catastrophes actually retard economic growth? How do real interest rates, inflation, budget deficits, and external debt respond to catastrophes? How important and how long lasting are the various effects likely to be? The purpose of this paper is to present observed changes in macro-economic risk factors that can be associated with the occurrence of catastrophes.

The paper presents cross-country data from 32 countries from all income groups affected by different types of natural hazards (earthquakes, floods, hurricanes, and droughts). These include 52 events.

There are few studies on the macro-economic effects of catastrophes. They are based on small data sets. Moreover, the conclusions are seemingly contradictory. Albala-Bertrand (1993:163) argues "GDP normally does not fall after a disaster impact and if anything tends to improve at least for a couple of post-disaster years." The World Disasters Report (1997) expresses an apparently opposite viewpoint. The report states: "Caribbean disasters can be costly, especially as a proportion of GDP. The impact on national economies has been significant: hurricanes between 1980 and 1988 effectively reversed the growth rates." Friesema et al. (1979) is an early study to analyze the effect of disasters on the long-term growth patterns of four cities - Conway, Galveston, Topeka, and Yuba City. They conclude that local economic behavior patterns, barring slight disruptions here and there, were scarcely interrupted by the disaster events considered. They also mention that their results are not surprising since in all the four cases the basic capital stock remained, and the production process continued. This makes their sample unrepresentative of catastrophes. Wright et al. (1979) examine data for over 3100 counties in the US for effects of disasters on growth trends of population and housing. Damage inflicted by the typical disaster in their sample affected only a small proportion

of structures, enterprises, and households of typical counties. Based on regression studies they conclude that there are no significant effects on disasters on growth trends in population and housing.

The inferences from these studies cannot be generalized to effects of catastrophe in a developing economy for several reasons. Firstly, the studies concentrate on regional localized effects in a developed country. Secondly, the direct loss is relatively small compared to the overall capital stock of the affected region. Finally, they only examine changes in a subset of indicators that describe the social and economic conditions of a region.

The next section describes the data used for the present study. The general framework and the particular econometric model used to estimate the effect of catastrophes is presented in the following section. Results of regression analysis are then discussed.

Change in Indicators Due to Catastrophes

There is an intimate relation between ongoing development processes and the occurrence of a catastrophe. The various parameters, which are associated with development such as education, infrastructure, and health, are hypothesized as measures of a community's robustness /vulnerability to a catastrophe. In the past decade there has been an explosion of empirical studies of growth and development. Efforts have been made to account for differences in growth rates between various countries using indicators of education, health, infrastructure, institutions, and political freedom. Results from these studies are used to identify variables that can make cross-country comparisons of changes in macro-economic indicators possible. The parameters will act to control some of the variability across countries. Any effect due to catastrophes on macro-economy can be detected only after the control variables explain variability from other sources. The present work relies on previous studies on the determinants of growth for choosing parameters that are associated with the development process.

One important indicator of development of a country is its economic growth. The following is a summary of some of the parameters that have been shown to be determinants of growth (Barro 1991, Barro and Lee 1993, King and Levine 1993, Easterly and Rebelo 1993, Fisher 1993, Easterly and Levine 1997, Easterly, Loayza, and Monteil 1997, Borensztein, De Gregorio, and Lee 1994). From these studies it has been shown that a percentage point in economic growth is associated with i) an increase of 1.2 years in average schooling of labor force, ii) an increase in secondary enrollment of 40 percentage points, iii) an increase of 1.7% of GDP in public investment in transport and communication, iv) a fall in inflation of 26 percentage points, v) a reduction in the government budget deficit of 4.3 percentage points of GDP, and iv) a fall in government consumption/GDP of 8 percentage points.

These results are used to identify the variables that can be controlled when making a cross-country comparison of post-event behavior of the economic growth rate.

DATA AND THE SOURCES OF AVAILABILITY

Data regarding major catastrophes that occurred around the world between 1980-1995 is obtained from Center for Research on the Epidemiology of Disasters (Sapir and Misson, 1992). This includes data on the type of the event, the time when an event occurred, the place of occurrence, the approximate estimated direct losses, and the number of people affected. Data regarding economic indicators such as average annual economic growth rate, gross domestic fixed investment and its growth, gross domestic savings, the resource balance, and government consumption and its growth are obtained from the World Development Indicators (World Bank, 1998). Data on money, inflation, transfers, and international exchange is obtained from Economic Freedom of the World - 1997 (Gwartney and Lawson, 1997). Data on institutions, bureaucracy, education, life expectancy, health, infrastructure are obtained from the web download-able databases maintained by Easterly and Levine (1997) and Barro and Lee (1995).

It should be noted here that the quality of data associated with catastrophes is not as good as data on macro-economic indicators. Only in the recent past have efforts been taken to document data from disasters like the EM-DAT database from CRED (Sapir and Misson, 1992). Recognizing that most reporting sources have vested interests and figures may be affected by sociopolitical considerations, CRED manages conflicts in information by giving priority to data from governments of affected countries, followed by UNDHA, and then the US Office of Foreign Disaster Assistance. Agreement between any two of these sources takes precedence over the third.

Catastrophes are relatively rare events by definition. In order to obtain a broad understanding of the effects of catastrophe in different countries, data has been compiled for catastrophes that have occurred in 32 countries. The World Bank classifies countries according to the income per capita. The four main categories in which the nations are classified are the high income, upper-middle income, lower-middle income, and low income. In the sample, there are eight countries belonging to the high income group ((>$9386 GNP per capita), Australia, Canada, Italy, Japan, Republic of Korea, Spain, UK, and US), five to the upper middle income group (($3036 - $9385 GNP per capita), Argentina, Brazil, Mexico, South Africa, and Puerto Rico), twelve to lower middle income group (($766-$3035 GNP per capita), Columbia, Dominican Republic, Ecuador, Fiji, Indonesia, Iran, Jamaica, Papua New Guinea, Peru, Philippines, and Thailand), and seven to lower income group ((<$765 GNP per capita), Bangladesh, China, Honduras, India, Nepal, Nicaragua, Pakistan).

It must be recognized that there is enormous variability in economic conditions within the countries. Many developing countries have groups that are very rich and further, many of them have a substantial middle class whose conditions of life are very different from the poor. In countries as vast as India, China, and Brazil regional as well as social variation can also be highly significant. Care should therefore be taken when interpreting results reported herein for such countries.

The sample has concentrated on post-1980 catastrophic events, with a few exceptions. This is because no cross-country study of the macro-economic effects for those events has been attempted. The study by Albala-Bertrand (1993) concentrates on a few events that occurred in the 1970s.

Generality of the inferences depend on including different hazard types in the sample. The present sample includes various types of natural hazards. It includes 22 earthquake events, 21 floods, 13 hurricanes or cyclones or typhoons or storms, 6 droughts, and 8 other events such as forest fires, volcanoes, cold waves, and landslides. It is important to find out whether the type of hazard has a significant effect on the nature of macro-economic changes.

Short-term effects are studied by comparing indicator values in the year preceding the event with the values in the event year. To discern the *long term* changes the effects of catastrophes mean values of the indicators are taken before and after the event and compared. Two years immediately preceding the event are chosen to calculate the pre event value. Post event value is calculated as the mean of three years (including the year of the event) after the event. In some cases events occur back-to-back. In such cases, the mean is taken based on a longer sample after the event.

GENERAL FRAMEWORK AND ECONOMETRIC MODEL

The general framework to be used in empirical studies reported here will be developed in this section. Theoretical models, reported elsewhere (Murlidharan, 2001), simulated the occurrence of a catastrophe as a perturbation of the 'normal' economic processes. A catastrophe was modeled as a reduction of capital and subsequent changes in productivity of the affected region. The economy was assumed to be initially in its steady state. Inspection of the theoretical model reveals that the evolution of physical capital after a catastrophe depends on the steady state and the perturbations. Growth of the economy in turn depends on the changes in capital stock. Hence, the following relation is used to estimate the effect of a catastrophe on the post-event growth rates:

$$\text{growth}_{\text{with hazard}} = f(\text{damage, productivity-changes; } y^{*}) \qquad (1)$$

y^* is the long-run steady-state level of per capita output and depends on the steady state levels of capital stock. y^* depends on an array of choice and environmental variables. The private sector's choices include saving rates, labor supply, and fertility rates, each of which depends on preferences and costs. The government's choices involve spending in various categories, tax rates, the extent of distortions of markets and business decisions, maintenance of rule of law and property rights, and the degree of political freedom. Also relevant for an open economy is the terms-of-trade, typically given to a small country by external conditions. A cross-country empirical analysis requires conditioning on the determinants of the steady states. Also, the pre-event conditions to a large extent determine the post event productivity. It is assumed that the country specific factors are invariant over the period of interest – five years. Data for these factors are typically available as constants over five- to ten-year periods.

Damage, in general, depends upon the intensity of the hazard and the vulnerability. Vulnerability is the susceptibility of the exposed constructed facilities, economic and social structures of a region to be affected given a specified level of hazard. Vulnerability is intimately related to ongoing socio-economic processes. Damage may be expressed as:

$$\text{damage} = h(\text{hazard, vulnerability}) \qquad (2)$$

It should be mentioned here the relation Eq.2 is expected to be highly non-linear. Even for relatively simple structures such as bridges, the damage curves – which relate the hazard intensity to the damage level (RMS, 1994) – are non-linear. Data regarding the loss of capital and the changes in productivity are hard to come by. Hence the loss of capital is modeled by the direct losses recorded after the event.

Approximation

The first step to estimate the model expressed in the relations (Eqs.1 and 2) above is to use an approximate linear relation. Consequently, the relation in Eq.1 is approximated by:

$$growth_{with\ hazard} = \alpha_1 + \boldsymbol{\beta_1 E} + \boldsymbol{\beta_2 Damage} + \beta_3 Hazard\_type + \varepsilon_1 \quad \ldots(3)$$

ε_1 is an unobserved disturbance term. The indicators for Damage are the direct-loss to GDP ratio and the percentage of population affected. **E** is a vector of country specific indicators of the economy that are considered as determinants of economic growth. The vector **E** contains indicators from each of the following categories of determinants of growth - Economic conditions, Individual Rights and Institutions, Education, Health, Transport and Communications, Inequality across income and gender. In particular the following indicators are used: Inflation variability, Average pre event decade growth rate, annual money growth, black market premium, political rights, civil liberties, bureaucratic quality, government enterprises, percent "no schooling" in population, daily protein or calorie intake, life expectancy at age zero, radios per capita, and TVs per capita. Hazard-type is a dummy variable to account for the type of hazard – earthquake, hurricane, or drought.

It should be mentioned here that Damage as such would depend on factors in the vector **E**. It is implicitly assumed that the indicators for damage are not correlated with the factors in **E**. This may be a strong assumption if the measure of loss is in terms destroyed of productive capital stock and **E** includes factors such as capital stock per worker. Indicators chosen in **E** are such that they are only indirectly related to direct loss term. Therefore, the assumption that **E** and damage are not significantly correlated is reasonable. It is also assumed that the errors in measurement/estimation of damage are not correlated with the error term η. The reduced form given in Eq.4.3 is estimated. The hypothesis to be tested is that the coefficients $\boldsymbol{\beta_2}$ are statistically significant and negative.

Similar models for other economic indicators are estimated where the dependent variable is chosen to be the post event budget deficit, external debt, resource balance, inflation, interest rates, or consumer price index. Again, the hypotheses to be tested are that the coefficients $\boldsymbol{\beta'_2}$ are statistically significant.

The next section presents general descriptive statistics of the data regarding economic growth.

Primary variables

Direct physical loss

One of the important variables that characterize a catastrophe is the resulting direct loss. Direct damages include all damage to fixed assets (including property), capital and inventories of finished and semi-finished goods, and business interruption resulting from a catastrophe. Estimation of the macro-economic effects involves a comparison of economic behavior with and without the change in a community's assets. The direct loss is one measure of the change in community assets after a catastrophe.

Comparing direct loss across countries necessitates an approach based on purchasing power parity (PPP). Converting the losses into a common currency, for e.g. the US dollar, through the use of official exchange rates often misleads cross-country comparisons of the losses. These nominal exchange rates do not reflect the relative purchasing power of different currencies, and thus errors are introduced into the comparisons. Using PPP is one way to obtain a correct measure of losses. In countries where the domestic prices are low, the losses based on PPP will be higher than that obtained from official exchange rates. For the purposes of this study we use ratio of loss (in current US dollars) to the GDP (in current US dollars) as a measure of direct loss. Using a ratio makes comparison of loss across countries valid, since PPP or exchange rates that appear both in numerator and denominator of the ratio cancel out.

Percentage affected

In a developing economy, where the majority are poor the number of people affected is often a better indicator of the severity of a catastrophe that direct loss. The number of people affected depends on the vulnerabilities of various groups that are resident in the affected area. The vulnerability of groups in turn depends on the manner in

which assets and income are distributed between different social groups. Post event recovery depends on the way resources are allocated and here too discrimination may occur based on pre-existing conditions of inequality based on gender, ethnicity, and race. It is these vulnerable sections of society that suffer most from catastrophes affecting their lives, their settlements, and their livelihoods.

Type of hazard

Different types of disaster have varying direct and therefore indirect and secondary impacts. Given a vulnerable habitat, the damage pattern depends on type and intensity of the physical event. For example, droughts ruin crops and forests but cause relatively little damage to infrastructure. As a result productivity may remain the same after the event. In the case of droughts, if the country has surplus of domestic food production, drought can be managed. For example, one year after the 1982 Australian drought the country's economy was back to 'normal'. But in countries with little surplus, the effects are more tangible. Countries whose GDP is mainly represented by the rural economies are especially vulnerable to droughts. Droughts cause major production losses. If the net farm income falls during a drought in a farm-based economy, it my cause a decline in the overall output.

In contrast, earthquakes cause relatively little damage to standing crops, other than localized losses resulting from landslides. But an earthquake can damage buildings and underground infrastructure. A hurricane may cause extensive crop damage as well as damage to structures. Reconstruction may result in changes to the productivity due to the destruction and subsequent construction of new capital. It is important to find out whether the type of disaster affects the post-event growth rates.

Control variables

Previous studies do not explicitly spell out the explanatory variables that may be related to the post-event economic growth rate. Theoretical models and simulations

presented elsewhere (Murlidharan, 2001) point to the importance for modeling the post-event productivity changes. Changes in the productivity are reflected in the post-event evolution of consumption, output, and growth. Based on a wealth of studies conducted in the field of economic growth, variables that may be important in determining the post-event productivity are discussed in the following sections.

Pre-existing Economic Conditions

If a nation has a stable macro-economy with a steady growth rate, it would be relatively easier to detect any fluctuations resulting from a catastrophe. Pre-event decade mean and standard deviation of the annual percentage growth rates are included as control variables, as indicators of past performance of a nation's macro-economy. Barro (1997) finds that higher inflation goes along with a lower rate of economic growth. Monetary institutions and policies that lead to substantial variations in the general level of prices create uncertainty and undermine the efficacy of money. In the event of a catastrophe, it is more likely in nations with high inflationary susceptibility that the prices will go out of control. Inflationary pressures will have a negative effect on the productivity. The standard deviation of the annual inflation rate during the last five years is included as a control variable (Gwartney and Lawson, 1997). Another indicator of monetary stability that is included is the average annual growth rate of the money supply during the last five years minus the potential growth rate of the GDP (Gwartney and Lawson, 1997). Other control variables include indicators of Health, Poverty and Inequality, Government, Bureaucracy, and Institutions, Infrastructure, Education, and Trade.

Summary Statistics and Discussion of the Sample

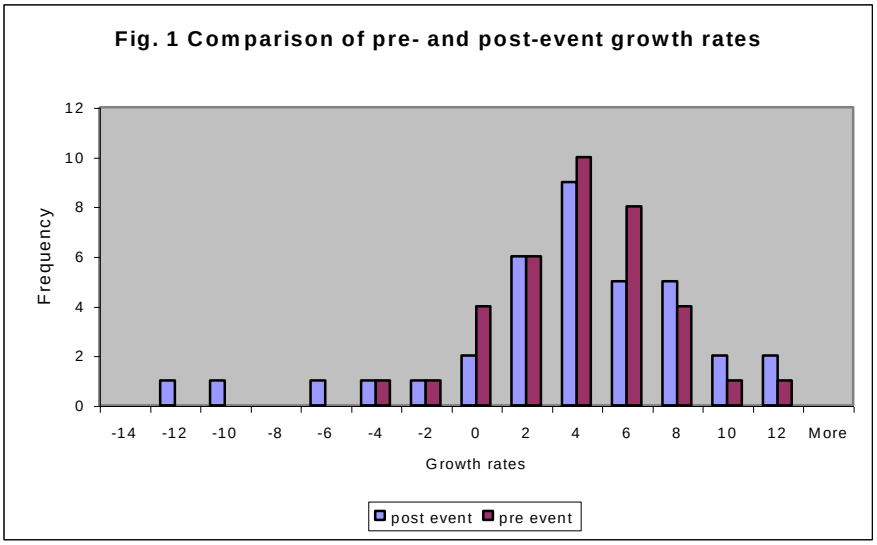
Economic growth

As a first step, the growth rates between two adjacent years are compared, that is, the growth rate during the event year is compared with the growth rate immediately preceding year. Both mean and median of the pre-event annual percentage-growth-rate are greater than their post event counterparts (Table 1). Presumably catastrophic events also induce greater variance for the growth rates, as evidenced by comparing the pre- and

post-event variances in the growth rates (Table 1). A histogram of the pre- and post event growth rates is shown in Fig.1.

Table 1 Summary statistics for short-term growth

	Pre event	Post event
Mean	3.15	2.56
Standard Error	0.56	0.88
Median	3.26	2.89
Standard Deviation	3.35	5.28
Sample Variance	11.22	27.90
Kurtosis	0.39	1.87
Skewness	-0.02	-1.08
Range	16.03	24.25
Minimum	-4.36	-12.50
Maximum	11.67	11.75
Sum	113.44	92.13
Count	36	36



It is apparent from Fig. 1 that the histogram for post event growth rate is shifted to the left relative to pre event growth rates, in addition to having lower frequencies for growth rates less than or equal to 6 percentage points. For growth rates greater than 6 percentage points, post event frequencies slightly exceed pre event frequencies.

LIMITATIONS OF CROSS-COUNTRY REGRESSION STUDIES

There are substantial conceptual and statistical problems that plague cross-country investigations (Levine and Zervos, 1993). Levine and Zervos (1993) point out that

statistically entries are sometimes measured inconsistently and inaccurately. Even putting measurement difficulties aside, it is not clear whether we can include countries as diverse as Bangladesh and Canada in the same regression. These countries operate in different policy regimes and under different environments. A country may be at a particular stage in a business cycle, or may be undergoing major policy changes, or experiencing political disturbances. All these factors affect economic activity and consequently economic growth. Researchers (Barro, 1991; Easterly, 1997) have found that many individual indicators of monetary, fiscal, trade, exchange-rate, and financial policies are significantly correlated with long-run growth in cross country growth regressions. How could one evaluate the "believability" of cross-country regressions? Extreme bounds analysis (EBA) based Edward Leamer's work can be used for testing the results of regressions relating the direct loss to the post event indicators of the economy. The EBA employs a linear, ordinary-least-squares regression framework. The variables in the vector **E** are chosen from a set of indicators, which are known to affect the long-run economic growth rate. The EBA involves varying the **E** variables to determine whether that coefficient on the damage indicator, **D**, is consistently significant and of the same sign when the right-hand-side variables change. If β_2 is consistently significant and have the same sign the results are termed as "robust"; otherwise the results are "fragile." The EBA is used to test the robustness of the empirical associations between the loss-GDP ratio and various economic indicators. The results of these regressions are presented next.

RESULTS FROM REGRESSION ANALYSIS

Regression results for short-term growth changes were based on a set of 26 specifications. Similarly, other sets of specifications were obtained on the effects of catastrophes on external debt, budget deficit, inflation, and the real interest rate. Details of these regressions are reported in Murlidharan (2001).

Growth rates – Short term

Summarizing from all the specifications, it is inferred that the direct loss term enters statistically significantly. The coefficient ranges from –3.9 to –1.7 with a mean of

–2.9 over the specifications. The coefficient for percentage of population affected is also statistically significant but is positive. The mean of this coefficient is 0.142 indicating that one percent of population affected is associated with 0.142 point increase in the post-event growth rate. Dummy for earthquakes indicate that they are associated positively and significantly with post event growth rate, whereas droughts are negatively associated with post event growth rate.

Some of the specifications control for immediate (one year preceding) pre event economic conditions with indicators such as the pre event growth rate, the pre event gross domestic fixed investment growth, and the pre event government size. The coefficients of pre-event growth rate and the pre event gross domestic fixed investment growth enter positively and significantly in explaining the post-event growth rate, as expected. One point of the pre event growth rate explains 0.39 to 0.79 point of the post event growth rate. One point growth in the pre event gross domestic fixed investment is associated with 0.22 points of post event growth rate. Greater share of the government expenditures in the GDP appears negatively associated with the post-event growth rate.

Control variables such as measures of civil liberties, bureaucratic quality, black market exchange rates, percentage of population without schooling are averages over longer periods of time, typically five to ten years around the event. The inherent assumption is that these variables change at a much slower rate than other macro-variables like the annual percentage growth rate. These factors nevertheless determine the vulnerability of a country to natural hazards, which in turn determines the post event economic behavior. The regressions present econometric evidence for associations between indicators of ongoing social, economic, and political processes and the post event behavior.

Indicators of the monetary health of an economy, namely the inflation variability, the monetary growth (average annual growth rate of the money supply during the last five years minus the potential growth rate of real GDP) is negatively associated with growth. Better bureaucracies are associated with higher post event growth. Indicators for government enterprises (higher ranks imply lower role and presence of government

owned enterprises) are positively associated with post event growth. Greater civil liberties and political rights are also positively and significantly associated with post event growth. Better health (as indicated by the daily protein/calorie intakes) is also positively associated with growth. Lack of education is negatively and significantly associated with post event growth. The signs and significance of the determinants of growth appear as expected.

Dummy for earthquakes indicate that they are associated positively and significantly with post event growth rate. Droughts are negatively associated with post event growth rate. Earthquakes typically result in capital being damaged or destroyed. Droughts do not cause relatively large damage to capital stock. After an earthquake, reconstruction activities may have a positive effect on the region's productivity. Numerical simulations (Murlidharan, 2001) indicated that increases in productivity result in increases in post event growth rates. Empirical evidence that earthquake dummy is positively correlated with the post-event growth rate lends support to the theoretical result that capital regeneration after an earthquake increases the post event growth rate. This is further reinforced by the fact that drought dummy is negatively correlated with post-event growth.

The coefficient of average pre-event growth rate enters positively and significantly in explaining the post-event growth rate, as expected. Greater is the pre-event growth greater is post-event growth. One point of the pre event growth rate explains 0.35 to 0.52 point of the post event growth rate.

Indicators of the monetary health of an economy, namely the inflation variability, the monetary growth (average annual growth rate of the money supply during the last five years minus the potential growth rate of real GDP) is negatively associated with growth. These indicators of the susceptibility of the economy to price volatility in an economy enter negatively because price increases after the event result in lower productivity.

Better bureaucracies are associated with higher post event growth. One possible reason is that better bureaucracies will fuel the post event productivity and hence growth. Lack of corruption enters positively and significantly in the post event growth rates. Indicators for government enterprises (higher ranks imply lower role and presence of government owned enterprises) are positively associated with post event growth. Greater civil liberties and political rights are also positively and significantly associated with post event growth. Better health (as indicated by the daily protein/calorie intakes) is also positively associated with growth. Lack of education is negatively and significantly associated with post event growth. The signs and significance of the determinants of growth appear as expected and in accordance with intuition.

EFFECT ON MAJOR ECONOMIC INDICATORS

After examining the data on economic growth rates, the effects of catastrophes on major economic indicators such as the external debt, the budget deficit, resource balance, inflation, consumer price index and the real interest rates are examined.

External Debt

Results indicate that direct loss is positively and significantly associated with the debt growth. The coefficient of the loss term has a minimum value of 2.0 and a maximum of 3.2 with a mean of 2.6 over the specifications. For example, one empirical expression for debt growth is the following:

debt_growth = -5.435 + 3.21*log(Loss/GDP)
(0.022) (0.000)
+ 1.190*(Economic Freedom Index) + 3.872*Flood
(0.005) (0.01)

N=31; R^2= 0.396; F=7.565; DW = 2.005

This implies that a direct loss of 10% of GDP is associated with 3.21 point increase in debt growth rate.

If debt growth is calculated as the change in the average pre- and post-event debts, then the coefficient of the loss term increases with a mean of 5.83. This implies that

catastrophic loss is associated with increase in the debt growth. Flood dummy appears positive and significant in the regressions.

Budget deficit

Results indicate that in specifications associating catastrophe variables with the post event budget deficit, the loss term enters negatively and significantly in all the specifications with a mean of –1.14. A typical relation is as follows:

$Deficit_{after}$ = -4.33 + 0.86 *$Deficit_{before}$-1.4*Log(Loss/GDP)

(0.002) (0.000) (0.011)

+ 2.395*Eq. + 0.559*GovtEnterp

(0.004) (0.006)

N=34; R2= 0.818; F=38; DW = 1.925

This implies that a direct loss of 10% of GDP is associated with 1.4 point increase in budget deficit (deficits are measured negatively).

Inflation and Real Interest rates

The regression associating the loss term and the inflation is as follows:

$Log(Inflation)_{after}$ = -0.27 + 1.22 *$Log(Inflation)_{before}$+ 0.09*Log(Loss/GDP)

(0.0018) (0.000) (0.053)

N=49; R2= 0.894; F=204; DW = 2.19

This implies that a direct loss of 10% of GDP is associated with 0.09 point increase in log(inflation)

The regression associating the loss term and the interest rates is as follows:

Int_rates_{after} = -1.1 + 1.0 *Int_rates_{before} - 4.45*Log(Loss/GDP)

(0.4) (0.000) (0.019)

N=36; R2= 0.772; F=60; DW = 2.233

This implies that a direct loss of 10% of GDP is associated with 4.45 point decrease in interest rates.

Summarizing the results of this section greater loss-to-GDP ratios are positively and significantly associated with external debt growth, budget deficit and inflation and are negatively and significantly associated with interest rates.

Summary Results and Limitations

The study conducted for finding empirical regularities in the ongoing socioeconomic processes after the occurrence of a catastrophe was addressed in this paper. The results of the regression analysis indicate that by studying disasters much can be learned about the way large-scale socio-economic systems affect and are affected by the occurrence of catastrophes. By making a cross-country study with countries from all income groups affected by different types of natural hazards, the results are expected to be sufficiently general. Previous empirical results from the literature on the determinants of economic growth and on economic development helped in identifying the explanatory control variables.

Summarizing the regressions on growth the following statistical regularities are discerned:

- The models indicate very significant negative coefficient for the direct loss variable in regressions for short-term growth. The coefficient for the loss variable in the long-term growth has a lower significance, but remains negative. The magnitude of the coefficient in the average growth rate regression is less than the short-term regression. This implies that the associations between the loss term and the economic growth rate become harder to detect with the passage of time.
- The pre-event economic growth rate is positive and very significantly associated with the post-event growth rate, in both the short-term and average regressions. This implies that, other variables being constant, an economy with a sufficient growth rate can absorb the effect of a catastrophe. Growth itself is an indicator of the robustness of ongoing developmental processes. This brings out the importance of having a robust

developmental process in place in absorbing the effect of a catastrophe. The coefficient for pre-event general government consumption is significant and negative. This agrees with the known fact that heavy consumption by the government sector retards growth.

- The coefficient for the percentage of people affected is positive and significant in short-term growth regressions. Though this seems odd, it is should be noted that a catastrophe affects many people only in developing countries. The amount of aid is to a certain extent decided by the figures regarding people affected. It is probably this external aid associated with the percentage affected that spurs growth.
- The coefficient for daily protein/calorie intake appears positive in the short-term growth regressions associating a healthier community with a more robust developmental process
- If the institutions of crisis management can be proxied by a combination of the size of the government and the efficiency of the bureaucracy, then their coefficients are positively and significantly associated with short- and long term (average) post event growth. This brings out the importance governmental bureaucracy in mitigating the effects of a catastrophe.
- The coefficient for inflation variability, which is a measure of the monetary robustness of an economy, is associated negatively and significantly with the post event short- and long-term growth. This once again ascertains the importance of the ongoing economic processes in explaining the post-event economic behavior.
- Other factors including civil liberties, percentage of no schooling, economic freedom index, freedom from corruption, and land-area had the expected signs. However the coefficient for black market premium and number of TVs per capita had unexpected signs.

The main results by of examining the effects of catastrophes on external debt, the budget deficit, inflation, interest rates gave the following results:

- A greater loss is associated with greater post-event external debt growth.
- A greater loss is associated with greater budget deficits.
- A greater loss is associated with higher inflation.
- An increase in the loss is associated with a decrease in interest rates.

There are limitations of the study, which are discussed in the following. The first is regarding the heterogeneity and panel data that arise naturally in cross-country studies. Omitted heterogeneity induces correlations between explanatory variables and the error term in a way that has the same consequences as simultaneity bias. The factors that appear on the right hand side of the specification such as pre event growth may have no general claim to exogeneity. The combination of genuine simultaneity and heterogeneity has the further effect of ruling out the use of lags to remove the former. These considerations would typically require further examination of the effect of catastrophe on the economic indicators using alternative specifications based on first differences. Another important limitation is the lack of appropriate instruments, which are correlated with direct loss term but un-correlated with error term. These instruments can be used to check whether the coefficients on the loss terms remain robust when they are instrumented. If data on sectoral distribution of losses is available, this can be used to instrument the direct loss variable. In other words, this requires details regarding losses in the agriculture, industry, and service sectors. But such data is hard to obtain. It would be ideal to develop a system of structural equations to explain the connections between all the macro-economic variables affected by catastrophes. Lack of underlying theoretical models forces us to use reduced form equations. These result in inference of statistical regularities as opposed to full-fledged causal models. Increase of representation in the sample of higher loss-GDP ratio events is required for the sake of generality. The disasters that have occurred in the immediate past (1996 to 2000) can be included in the sample.

There were several contributions as a result of this study.

How important and how long lasting are the various effects likely to be?

Catastrophe results in loss of capital and this loss combined with the changes in the productivity of the affected economy results in overall welfare losses. A measure of the secondary effects of catastrophes based on these welfare losses was devised, which was can be used to assess to impact of a catastrophe on an economy.

What trends do past data on catastrophes suggest and can theoretical models replicate these trends?

Data based on past catastrophes suggest a negative correlation of the loss with the post event growth rate. Theoretical model, by modeling the efficiency of post-event reconstruction was able to explain this negative correlation between the loss and the post event growth rate. The observation that earthquakes were associated positively with the post event growth rates were explained by the fact that reconstruction of destroyed or damaged capital results in increases in productivity of the region which in turn spurs the post-event growth rates.

How closely are catastrophes and developmental process related? Do catastrophes actually retard economic growth?

Catastrophes should be viewed as opportunities. As has been argued in the previous chapters, vulnerability of a region to catastrophes is intimately related to the on going socioeconomic processes including development. If the threat of occurrence of natural hazards is taken into account while designing the development program of a region, then it may result in building of robust engineering as well as social structures. Ex ante a catastrophe-threat induced preparedness programs could result in many positive externalities.

Ex post catastrophes can result in the building of a robust and less vulnerable region, if appropriate measures are taken. The theoretical models (discussed in Murlidharan, 2001) and empirical data presented in this paper bring out the importance of pre-event conditions and efficiency of post-event reconstruction in determining the evolution of an economy after an event. The occurrence of a catastrophe gives the opportunity to invest, rebuild, and revitalize the economy of the affected community. If this opportunity is seized, the affected community could emerge better off than it was prior to the event.

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