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Natural Disaster Situations and Growth: A Macroeconomic Model for Sudden Disaster Impacts

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Summary. — The aim of this paper is to examine the relation between a natural disaster situation and its potential effects on the growth rate of output, by means of a simple macroeconomic model, which is later applied as a demonstration to a sample of countries affected by major natural disasters in the last two decades. This quantitative application appears to support the model. The main conclusions are that capital loss is unlikely to have an important effect on growth and that a very moderate response expenditure may be sufficient to prevent the growth rate of output from falling. A general derived conclusion is that foreign and public disaster response may be better used to help actual victims and affected activities directly than to proceed on the rather unsound *prima facie* belief that the economy will be heavily affected by the disaster.

1. INTRODUCTION

It is customary to believe that major natural disasters (see glossary in the appendix) are likely to have a large negative impact on economic growth. From newspaper headlines to more specialized sources, there appears to be a received wisdom about these effects. After any visually impressive disaster, newspapers invariably show explicit photographs of havoc under sensational headlines. Their stories portray a picture of devastation and tragedy that is normally based on the correspondent's direct observation, official statements, and hasty interviews with local authorities and emergency personnel. They are often based on highly unreliable data such as the number of casualties (deaths, injured, missing, homeless) and the cost of the material losses (destruction, damage). These data stem from the first estimates of general losses, which have been shown to be normally highly overestimated by Albala-Bertrand (1993 and 1992c). This is not just due to journalists' creativity, for official sources often contribute to these perceptions.[1] Ordinarily there are also a few brief sentences about the way the economy would be affected. Remarks such as "a serious setback in economic development," "economic development will suffer considerably," "the development drive will be seriously hampered," or "the economic potential of the country seems seriously affected" are common. Similar statements may be made about economic indicators such as the rate of inflation (forecast to rise), the balance of payments (expected to worsen), the rate of unemployment (predicted to increase), the GDP (likely to deteriorate) and so on.

Is this true? Are these a set of features common to all major disasters? Specialized authors in the field of disaster are generally more cautious about economic effects of disasters, but end up with statements such as "however, it is also possible that if adequate aid is not provided, that the previous rate of development will not be attained again and the result will be long-term stagnation" (Krimgold, 1974, p. 4). Assertions such as this are most characteristic of relief professionals, but views in the same direction are certainly not absent among other researchers, including economists, e.g., Long (1978), Abril-Ojeda (1982) and Jovel (1989). These notions are likely to be the result of inferences from partial analysis of disaster that fails to grasp the web of interactions between the affected area and the rest of the economy, neglecting that the domestic economy and polity are an ever-active system of institutions hardly hampered by setbacks and interferences such as disasters. Local disaster severity may well make little difference for the

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ongoing global processes. Local (see Rule I below)[2] cannot be equated to national, neither can human tragedy be equated to economic setback, and nor can recovery be equated to only financial, or international, aid.[3]

International organizations do not appear to fare a lot better on this score. For example, UNDRO (Office of the United Nation Disaster Relief Coordinator) began operations in 1972 and was established for the purpose of mobilizing and coordinating relief speedily and systematically, and reducing the risks of waste and duplication of effort. UNDRO, until its incorporation into the Department of Humanitarian Affairs (DHA) in 1991, undertook and commissioned a series of disaster studies in the various fields of science, the purpose of which was:

> to provide the international community with a comprehensive review of existing knowledge of the causes and characteristics of natural phenomena and the preventive measures which may be taken to reduce or eliminate their impact on disaster-prone developing countries . . . [because] . . . the effects of natural phenomena must be viewed not only in humanitarian and broad social terms, but also — and primarily — in economic terms (UNDRO, 1976–82, p. iii).

UNDRO's publications consider natural disasters as a formidable obstacle to economic development. For example, "disasters constitute a major development problem for most disaster-prone countries" (UNDRO, 1976–82), p. 2. Or "in terms of percentage of gross national product, the losses caused by disasters in some disaster-prone developing countries more than cancel out any real economic growth" (p. iv). Or "one major disaster or series of disasters can cancel out years of growth" (UNDRO, 1987).

The fact, however, is that the economic effects of large localized natural disasters (see Rule I below and glossary) rarely affect negatively actual aggregate output. If anything there often appears to be a positive short-term effect on GDP (see Rule V below). One of the main conclusions about large natural disasters is that as a rule their effects "are primarily a problem *of* development, but essentially not a problem *for* development (Albala-Bertrand, 1993).[4] Is the linkage between disaster damage and economic growth a sound one? Are disasters really a formidable obstacle to economic growth? Has the ratio disaster loss-to-GNP any relation with "heavy impact on the economy"? It will be shown that such a relation is not sound. To that purpose, I show through a simple macroeconomic model, standing on well-supported assumptions about natural disasters, that a localized disaster impact, especially a sudden one, is normally not likely to affect growth rates significantly, and that the response effort to prevent any such effect is far from dramatic. The model is then applied to a sample of large Latin American disasters occurring in the last two decades.

It should be stressed that a "slowly developing" disaster (see glossary), such as a drought, by affecting agricultural capital in a gradual and cumulative rather than instantaneous way, may have more important and longer lasting indirect (flow) effects than a "sudden" disaster. But, in more diversified economic settings, where alternative resources are more readily available, it may also have more permanent and stronger endogenous counteractions (see glossary), especially substitutions, compensating and neutralizing also over time the negative effects at the macro level.[5] The model and its later application, however, has been set up to deal primarily with "sudden impact" natural disasters. This also implies that "human-made" disasters such as wars, riots, technological failures are excluded in principle.

2. BACKGROUND: DEFINITIONS AND RULES

Before setting up the model, let us introduce both some definitions (see glossary) and a few disaster rules (or well-supported assumptions). First, we define a disaster situation as an event comprising three analytically separable components: the disaster impact, the disaster response, and the incidental disaster interference. The focus of this paper is the disaster situation, although for reasons of space we do not deal with disaster interference.[6] We also distinguish between direct (stock) effects and indirect (flow) effects of disasters. In our framework, the former is the matter of reconstruction, normally a long-lasting activity, whereas the latter is the matter of emergency, normally a short-lived activity. Our analytical starting point is when the emergency is well underway or has been completed, and as we consider indirect effects of disaster either highly speculative or rarely persistent (see Albala-Bertrand, 1993), we concentrate only on the growth consequences of the direct disaster effects on capital and current output.

Second, for economic analysis, we define a large natural disaster (see glossary under disaster size) as that which has a large loss-to-GDP ratio, let us say, the size of the country's average growth rate (e.g., 5%). This ratio, however, is only a basic condition for potentially harmful economic effects, therefore, it should not be taken as an interchangeable expression for "heavy impact" on the economy. It is also true that a smaller ratio, in a comparable economy, can have worse economic effects if the event happens to strike in a particularly sensitive area of activity. For example, the 1987 earthquake in Ecuador represented a loss ratio of only 1.8%, but it destroyed one of the most important oil pipes in the country, cutting down for several months oil exports and foreign exchange availability (ECLA, 1987). This unfortunately localized impact is, however, rare among disaster stricken countries. Therefore, for the purpose in hand, other things being equal, we take the loss ratio as an indicator of disaster size.

Third, a number of disaster rules put forward by Albala-Bertrand (1993) can be used as well-supported assumptions for the ensuing model (see Table 1).[7]

Rule I means that disasters directly affect either only a geographically localized area of activity, i.e. a spatially confined part of the social system, or only an economically localized area of activity, i.e. an economically confined part of the social system, or both (see Note 2 and glossary). Rule II means that both the magnitude of an event and the social vulnerability to given magnitudes are not the same throughout a disaster area (see glossary). Corollary (a) means that there will be internal (disaster area) coexistence of affected economic units with unaffected ones of the same economic sector. Corollary (b) means that disasters have a greater effect on the more marginal sectors (or units within sectors) of society, i.e. most labor affected is both largely unskilled and less productive than average, and most affected capital (residential, infrastructural capital and fixed capital) is of lower quality and productivity than average. Rule III means that the various capital stock types are not equally affected by disasters and that a patterned distribution of capital losses according to disaster type can be discerned.[8] Rule IV means that disaster losses are highly overestimated due to both political and technical reasons (see Note 1). Rule V means that GDP and inflation are not affected negatively by disasters (see Note 4). Rule VI simply means that disasters are few and far between.

3. THE MODEL

(a) *Impact: Upper level*

Let us first set an upper limit for output fall from disaster capital loss, under the following working assumptions:

(i) Disaster emergency is well under way or has been completed.[9]
(ii) Materials stocks are available.
(iii) Fixed capital stock loss is unreplaceable in the short term.
(iv) All losses are to capital stocks.
(v) Capital stocks are homogeneous.

Given (iv) and (v):

$\Delta K = D$ where $\Delta K = K_a - K_b$ (capital loss) (1.1)

K : capital
D : total disaster loss
b : before disaster impact
a : after disaster impact

Assuming that the global capital-output ratio is the same as that for the loss:

$c = K/Y = \Delta K/\Delta Y$ where

c : capital-output ratio (1.2)
$\Delta Y = Y_a - Y_b$ (expected output loss)
Y = output (income)

Solving (1.2) for ΔY and substituting ΔK for D:

$$\Delta Y = D/c \qquad (1.3)$$

Transforming (1.3) into a growth rate by dividing both sides by Y:

$y = d/c$
where $y = \Delta Y/Y$: growth rate of output (fall) (1.4)
and $d = D/Y$: loss-to-output ratio

Therefore, the expected fall in growth rate of output (y) is in direct relation to the ratio of disaster loss to total output (d) and in inverse

Table 1. *Disaster rules*

Rule I :	Confined localization.	
Rule II :	Internal differentiation of effects.	
Corollary II(a):		Local sectoral coexistence.
Corollary II(b):		Marginal toll.
Rule III :	Differential and patterned damage to capital stocks.	
Rule IV :	Overestimation of losses.	
Rule V :	GDP and inflation stability.	
Rule VI :	Infrequency of disasters.	

relation to the capital-output ratio (c). For the Guatemalan earthquake of 1976, equation (1.4) is valued at[10]:

$$y = d/c = 0.17/4.67 = 0.036 = 3.6 \text{ percentage points}$$

This would represent a significant loss, but this also represents a very unrealistic upper limit, especially because assumptions (iv) and (v) are highly inadequate.

(b) *Impact: Lower level*

Dropping assumption (iv) implies that $\Delta K < D$, since a fraction of disaster losses is not to capital but current output. In turn, dropping assumption (v) implies that as ΔK is heterogeneous, c must be reevaluated in accordance to the productivities of the losses to the various capital stocks. This plus Rule IV and some accounting practices give us six factors to be incorporated into equation (1.4) so as to arrive at a more realistic lower level and hence to an interval for the expected fall in the growth rate of output due to capital loss. The factors are:

(i) Not all disaster losses are to capital stocks.
(ii) Disaster losses are as a rule overestimated.
(iii) Capital loss is normally estimated at replacement cost.
(iv) Capital is productively heterogeneous across capital types.
(v) Capital is also productively heterogeneous within capital types.
(vi) Growth of output does not depend only on the physical stock.

The corrections according to the first three factors will only affect the numerator of equation (1.4), whereas the latter three factors will only affect the denominator of that equation. The end result will give us an equation for the lower limit of the expected decrease in the growth rate of output.

First, by dropping assumption (iv), factor (i) can be incorporated as follows:

$$D = D_1 + D_0 \tag{2.1}$$

where D_1: total capital loss
D_0: total loss of current production

Therefore, by substracting D_0 from total losses (D), equation (1.1) is reevaluated as:

$$\Delta K = D - D_0 = D_1 \tag{2.2}$$

Second, using Rule IV, as disaster losses are normally overestimated (factor ii), the declared losses must be corrected by multiplying total losses by a coefficient smaller than one (e.g., a coefficient equal to 0.8 means that the true value of losses is 80% of that officially declared). That is, for capital loss:

$$D_2 = \varepsilon D_1 \tag{2.3}$$

where D_2: capital loss corrected for overestimations[11]
$\varepsilon < 1$

Hence, by correcting D_1, equation (2.2) becomes:

$$\Delta K = D_2 = \varepsilon D_1 \tag{2.4}$$

Third, as capital cost is calculated at replacement cost (factor iii), the depreciation should be discounted to assess the actual loss of productive potential from capital loss. Otherwise, the effect of capital loss would be overestimated. That is,

$$D_3 = \pi D_2 = \pi\varepsilon D_1 \tag{2.5}$$

where D_3: actual cost of capital loss
π : reciprocal of depreciation rate, i.e. $\pi = 1 - \lambda$ and $\lambda = T/D_2$
T : depreciation

Therefore, by correcting D_2, equation (2.4) becomes:

$$\Delta K = D_3 = \pi D_2 = \pi\varepsilon D_1 \tag{2.6}$$

Fourth, as capital is heterogeneous across stock types (factor iv) and, according to Rule III, the less-productive types of stock are more affected by disasters, the average capital-output ratio for the capital loss will be larger (i.e. less productive) than the global average. This can be incorporated by multiplying the normal c by a coefficient larger than one. That is,

$$c_1 = \alpha c \tag{2.7}$$

where c_1 : capital-output ratio corrected according to factor iv
$\alpha > 1$

Fifth, as capital is also heterogeneous within stock types (factor v) and given that capital losses are to the less productive capital within any type (Rule II and Corollaries IIa and IIb), the average capital-output ratio for the capital loss will be larger than the global average. This can be incorporated by multiplying c_1 by a coefficient larger than one. That is,

$$c_2 = \beta c_1 = \alpha\beta c \tag{2.8}$$

where c_2 : capital-output ratio corrected according to factor (v)
$\beta > 1$

Finally, as output does not depend only on capital contribution, noncapital factor contribution should be considered for a more realistic evaluation (factor vi). This can be incorporated by multiplying c_2 by a coefficient larger than one (e.g., equal to two, if labor is the only other factor and contributes with 50% of total output). That is,

$c_3 = \gamma c_2 = \gamma\beta c_1 = \gamma\beta\alpha c$
where c_3 : capital-output ratio corrected (2.9) for noncapital factor contribution
$\gamma > 1$

Therefore, by incorporating all the above corrections, equation (1.4) becomes:

$$y = d_3/c_3 \quad (2.10)$$

Or in a disaggregate presentation:

$$y = (\pi\varepsilon/\alpha\beta\gamma)\ (d-d_0)/c \quad (2.11)$$

In addition, this is the lower limit for the expected loss of the growth rate of output due to disaster capital loss. Therefore, the expected loss of growth rate of output is to fluctuate as follows:

$$d_3/c_3 \leqslant y < d/c \text{(expected loss interval)} \quad (2.12)$$

It should be stressed again, however, that the actual fluctuation will be closer to the lower limit, for the upper limit is absolutely unrealistic. For example, for Guatemala 1976 (earthquake), $d_1 = 0.15$ (or $d_0 = 0.02$) and assuming $\alpha = \beta = \gamma = 2$, $\pi = 0.9$ and $\varepsilon = 0.8$, which are not particularly extreme coefficients, the interval depicted in equation (2.12) will in percentage points be valued at around: $0.3 \leqslant y \leqslant 3.6$, which is not a dramatic fall of expected growth rate of output, especially as we should realistically expect the fall to be closer to 0.3 percentage points.[12]

(c) *Response: Minimum compensatory investment*

The question is by how much investment (or expenditure) should increase to compensate exactly for the potential expected loss of output. Let introduce some additional working assumptions:

(vi) Any additional response beyond emergency goes only to replace capital. Let us call it reconstruction investment.
(vii) Reconstruction investment represents autonomous expenditure on capital,
(viii) There is enough idle capacity in the economy, particularly in the construction sector.

Given assumption (i), there could be no important bottlenecks caused by the disaster disruption alone. This implies that the multiplier of autonomous expenditure (on capital reconstruction) will smoothly operate.[13] Therefore,

$\Delta Y = m\Delta I_r$
where m : multiplier (3.1)
I_r : reconstruction investment
Y : income (output)
Δ : variation
$m \geqslant 1$

Or dividing both sides of equation (2.1) by Y:

$$y = m\Delta v \quad (3.2)$$

where $v = I_r/Y$: investment coefficient or ratio

This means that, as m $\geqslant$ 1, for each unit of variation in the investment coefficient (v), the growth rate of income (y) is expected to increase by m. But, contrariwise, equation (2.10), i.e. $y = d_3/c_3$, means that, as $1/c_3 < 1$, for each unit of capital loss ratio (d_3), the growth rate of income (y) is expected to decrease by $1/c_3$. As $m > 1/c_3$, this implies that each unit of capital replacement will more than compensate the decline of expected income from each unit of capital loss.

For example, if $m = 2$ and $c_3 = 10$, one unit of capital loss represents a fall of 0.1 units of expected income, whereas one unit of capital replacement represents a rise of two units of expected income. That is, in this example, income from replacement represents 20 times as much as income from capital loss. This means that to compensate income fully for the expected loss, there is no need for full reconstruction at any one moment. So reconstruction may be spread over a number of years according to the amount necessary to compensate or counterbalance income. That is, equalizing equation (3.2) to equation (2.10), i.e. making the rise equal to the fall, and solving for Δv:

$$\Delta v = d_3/mc_3$$
(compensatory investment ratio) (3.3)

Therefore, this is the minimum required increase in the investment coefficient to compensate fully for the expected decrease in the growth rate of output from capital loss in the first postdisaster year. Let us call it "compensatory investment ratio." Following our previous numerical example, $\Delta v = d_3/20$, so one twentieth of the corrected loss ratio would be exactly enough to compensate income in the first year. That is, if $d_3 = 0.01$ (i.e. 1% of output), to compensate fully the economy for the potential fall in the growth rate of output, in the first year, the investment ratio would have to increase by 0.05 percentage points more than otherwise it would have been (i.e. with no disaster).

Let us recall the case of the 1976 Guatemala earthquake. Using equation (3.3) and assuming a $m = 2$, the lower limit for the reconstruction investment coefficient for the first year (Δv_1)

will be around 0.15 percentage points. The upper limit will be around 1.8 percentage points. Thus, the interval, expressed in percentage points, is $0.15 \leqslant \Delta v_1 < 1.8$. But as indicated only the lower limit is relevant. Therefore, this means that to compensate fully for the expected loss in the growth rate of income, in the first year, the investment coefficient should be 0.15 percentage points more than otherwise it would have been (i.e. with no disaster). This certainly is not an important effort for the aggregate economy.[14]

(d) *Response: Minimum compensatory investment over time*

To assess the way compensatory investment can be spread over time, we add the following simplifying assumption: (ix) Capital replaced is of the same quality as that of capital loss.

Therefore, at the end of the first year, productive potential would have recovered by the amount (in ratio terms) of reconstruction investment of that year (Δv_1), so it must be discounted from the total capital loss ratio (d_3), i.e. one-twentieth (1/20) of it in our numerical example. Let us use a numeral subindex indicating the corresponding postdisaster year. Therefore, at the end of the first year the remaining capital loss (in ratio terms) would be ($d_3 - \Delta v_1$) rather than d_3, so the compensatory investment ratio required for the second year would be:

$$\Delta v_2 = \frac{d_3 - \Delta v_1}{mc_3} \tag{4.1}$$

And at the end of any year, the following generalization applies:

$$\Delta v_i = \frac{d_3 - \Sigma \Delta v_{i-1}}{mc_3} \tag{4.2}$$

where $\Delta v_0 = 0$
i : 1, 2, . . .n (years)
Σ : sum over i

Or derived from (4.2), as a geometrical series:

$$\Delta v_i = \Delta v_1 \ (1 - 1/mc_3)^{i-1} \tag{4.3}$$

For example, assuming $m = 2$, $c_3 = 10$ and $d_3 = 0.01$, the following series, in percentage points, can be generated: 5, 4.75, 4.51, etc. More conventionally, the above is a geometric series, the ratio of which is $r = (1 - 1/mc_3) = 19/20 = 0.95$ and the first term is $\Delta v_1 = 0.05$, so the series can generically be written as:

$$\Delta v_1 r^0,\ \Delta v_1 r^1\ \Delta v_1 r^2,\ . . . .,\ \Delta v_1 r^n \tag{4.4}$$

This is a decreasing series which converges to zero as n tends to infinity. The implication is that the reconstruction effort can be spread over a large number of years with no negative consequences on aggregate income, and thereby with little sacrifices of funds from other developmental projects at any one year. This will of course depend on the particular values of the multiplier (m), the corrected capital-output ratio (c_3) and the corrected capital loss ratio (d_3). It can be shown that the larger the multiplier and the capital-output ratio, the smaller $1/mc_3$ and the closer to one the ratio r. The closer this ratio is to one, the smaller the required investment amount for reconstruction in any one year. Conversely, the smaller m and c_3, the larger $1/mc_3$ and the closer to zero the ratio r. The closer this ratio is to zero, the larger the required initial reconstruction investment and, therefore, the shorter the significant spread period.

For example, if $d_3 = 1$ (percentage point), $m = 5$ (i.e. a high multiplier) and $c_3 = 50$ (i.e. a very high corrected capital-output), the series will in percentage points be: 0.004, 0.0039, 0.0039, etc. If, in turn, $m = 1$ (i.e. no multiplying effect) and $c_3 = 2$ (i.e. a very low corrected capital-output ratio), the series will in percentage points be: 0.5, 0.25, 0.13, 0.06, 0.03, 0.02, 0.008, etc. Reconstruction effort to counterbalance expected income loss at any one time will be even less important if assumption (ix) is lifted, because the series figures will become even smaller as capital loss is replaced with capital of higher productive quality, which as regards reconstruction may be more realistic. Finally, if there are a number of large disasters striking in the same country, the series coming from each of them will add up, making it more difficult to achieve the required compensatory investment, but that is unlikely as disasters are few and far between (Rule VI).

(e) *Total compensatory expenditure required*

All the above accounts for potential GDP (or income) loss from capital loss. As a fraction of total losses are to current GDP, this should be also compensated. This will be a once-and-for-all expenditure incurred only in the first year. Therefore, in the first year, this should be added to the investment expenditure above. If impact (contractionary) and response (expansionary) income multipliers are symmetrical, then exactly the same amount of additional expenditure will be necessary to compensate for the current income loss. But if, as argued in Albala-Bertrand (1993), impact multipliers are smaller than response multipliers, which is more likely, then compensatory expenditure will be only a fraction of the current income loss. That is, the total compensatory expenditure required in the first year will be given by:

$$\Delta e_1 = (m_1/m_2)\ d_0 + \Delta v_1 \qquad (5.1)$$

where e_1 : total required expenditure ratio in the first year
v_1 : minimum compensatory investment ratio in the first year
d_0 : current output loss ratio
m_1 : impact multiplier
m_2 : response multiplier

For Guatemala's lower limit, if $m_1 = m_2$ (i.e. if impact and response multipliers have the same strength), then $\Delta e_1 = 2 + 0.15 = 2.15$ percentage points more than it otherwise would have been (i.e. with no disaster). If $m_2 = 2m_1$ (i.e. if response multipliers are twice as strong as impact multipliers), $\Delta e_1 = 1 + 0.15 = 1.15$ percentage points more than it otherwise would have been. This is certainly a heavier but not dramatic requirement, and even less if national and foreign aid plus endogenous responses (see glossary) are taken into account. Notice that the emergency by itself represents expenditure in the economy. Therefore, after the emergency has been completed the above requirement to compensate for current output loss will be even smaller.

4. AN APPLICATION TO ACTUAL DISASTER SITUATIONS

Let us apply equation (5.1) to six disaster situations in Latin America. Table 2 characterizes the six countries in our sample according to some relevant economic and disaster-related variables. The subsequent tables are presented as follows: the first three columns are for the country names, disaster dates and disaster type; the following five columns correspond to the immediate two predisaster years, the disaster year, and the immediate two postdisaster years. Every time the disaster struck in the last quarter of a year, the year that follows is taken as a disaster year.

It should be noted that according to our disaster size definition (see glossary) only five of the cases can be considered as large, the odd case being the Ecuadorian floods (i.e. with a disaster loss-to-GDP ratio of only 0.9%).

Table 3 shows the evolution of the real growth rate of GDP over the five-year period. It can be seen that except for Honduras and Ecuador, the countries show both positive and improved growth rates in the disaster year and thereafter, especially in Nicaragua. The two exceptions can be shown to be the result of causes unrelated to the disaster, although the hazard itself may have worsened an already bad situation.

Table 4 shows the rate of inflation. Except for Honduras and Ecuador, all other countries appear to present a common pattern: the rates of inflation in the disaster year are either smaller or similar to the predisaster average. For Nicaragua there is no information on CPI variation before 1972, so there is no way to compare. There could have been, however, an acceleration of inflation from 1973 on account of both the first oil shock and negative terms of trade, as indicated in IMF "Supplement on Economic Indicators" (1985), but the significantly higher growth rates of both 1973 and notably 1974 may have overheated the economy also accounting for higher, although not accelerating inflation. The rates for the two odd cases reflect more domestic ongoing problems than disaster-related factors, although the two may have interacted.

Table 2. *Disaster affected countries: Some relevant variables**

Country	Date	E	P	t	GDPpc	F	I	A	H	D	a(h)	d
Peru	3/70	Eq	13.5	11	1470	50.0	30	950	600	1600	7.0	8.1
Nicar.	12/72	Eq	2.0	13	1350	10.0	20	250	250	2300	12.5	85.1
Hondur.	9/74	Hn	3.0	27	850	8.0	—	150	142	1150	4.7	45.1
Guatem.	2/76	Eq	6.2	57	1400	27.0	80	1700	1700	1450	27.4	16.7
Dom. R.	9/79	Hn	5.3	110	1650	2.0	4	2000	660	1300	37.7	14.9
Ecuad.	11/82	Fd	8.6	19	1940	0.1	—	450	40	150	5.2	0.9

Source: Prepared from ECLA, CRYRZA and IMF.
E: event or disaster, P: population (million), t: density (people per Km^2), GDPpc: Per capita Gross Domestic Product (US$, 1987), F: deaths (thousand), I: injured (thousand), A: affected (thousand), H: homeless (thousand), D: loss value (US$ m, 1987), a(h): affected-(or homeless)-to-population ratio (the larger of the two, percentage), d: total loss-to-GDP ratio (percentage), Eq: earthquake, Hn: hurricane, Fd: flood.

Table 3. *Real growth rate of GDP*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	0.2	4.1	7.3	5.9	6.8
Nicaragua	12/72	Eq	4.9	3.2	6.4	13.5	2.2
Honduras	9/74	Hn	3.1	5.6	−0.3	−1.7	8.4
Guatemala	2/76	Eq	6.4	1.9	7.4	7.8	5.0
Domin. Rep.	9/79	Hn	5.0	2.1	4.5	5.6	4.2
Ecuador	11/82	Fd	3.9	1.2	−3.1	4.2	4.3

Source: UN, *Yearbook of National Accounts* (various years), ECLA, *Statistical Yearbook for Latin America* (various years).

Table 4. *Inflation rate (Consumer's Price Index variation)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	19	6	5	7	7
Nicaragua*	12/72	Eq	—	—	25	15	8
Honduras	9/74	Hn	5	5	13	6	5
Guatemala	2/76	Eq	17	13	11	13	8
Domin. Rep.	9/79	Hn	13	4	9	17	8
Ecuador	11/82	Fd	13	16	48	31	26

Source: IMF, *Government Financial Statistics Yearbook* (various years), ECLA, *Statistical Yearbook for Latin America* (various years).
*CPI variations for Nicaragua are unavailable before 1974. The above is from IMF, but the source of which is not reported. For the sake of having some data, I include it as an unreliable indication of inflation.

To explain the above aggregate results, especially those of the two odd countries, we can observe both related aggregate variables and other domestic factors.[15] The stagnant or negative growth rates of construction (see Table 5) in the two stagflationary countries are a sure indication of serious domestic (and international) problems unlikely to be related to the disasters. They also show a meager disaster response, contrary to the significant increase everywhere else, notably Nicaragua and Guatemala. As expected in developing countries, this is also confirmed by the growth rate of gross fixed capital formation (GFCF), given that construction represents here one of the main contributors to this rate (see Table 6). The public deficit, in turn, fell only in Nicaragua and Ecuador, and increased significantly especially in Guatemala and Dominican Republic (see Table 7). This shows a poor general disaster response in Ecuador in which, contrary to Nicaragua, the overall (private and public) investment effort was also poor, as indicated by the negative GFCF growth rate in the disaster year. The trade deficit (Table 8 and 9), except for Peru and again Ecuador which show surpluses, increased or stayed at high levels. Except for Honduras, however, the international reserves increased significantly everywhere (Table 10), resulting from significant capital inflows in all countries, except for Peru and Ecuador. In other words, these two surplus countries increased their reserves despite showing important outflows of capital (Table 11). As expected in a disaster, unrequited transfers, i.e. official and private donations, increased significantly everywhere, notably Nicaragua, Guatemala and Dominican Republic (Table 12). Therefore, except for Honduras, the trade deficit was financed without a loss of reserves.

It should be stressed here that, as expected, the disaster situation in all cases appears mixed with ongoing social and political developments. For example, at the time of the earthquake, Peru

Table 5. *Construction (real growth rate)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	16.4	6.7	0.2	9.2	10.7
Nicaragua	12/72	Eq	3.5	9.0	16.2	51.4	−3.2
Honduras	9/74	Hn	7.0	8.7	0.0	4.0	3.8
Guatemala	2/76	Eq	−6.6	15.2	73.8	12.5	2.8
Domin. Rep.	9/79	Hn	16.8	2.3	5.4	−0.5	−4.0
Ecuador	11/82	Fd	4.8	0.6	−7.6	−2.2	2.4

Source: UN, *Yearbook of National Accounts* (various years), ECLA, *Statistical Yearbook for Latin America* (various years).

Table 6. *Gross fixed capital formation (GFCF) (real growth rate)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	15	−3	3	9	3
Nicaragua	12/72	Eq	3	−11	37	22	−9
Honduras	9/74	Hn	5	28	2	13	8
Guatemala	2/76	Eq	−2	10	37	9	9
Domin. Rep.	9/79	Hn	10	1	13	−9	−11
Ecuador	11/82	Fd	1	−26	−5	7	4

Source: UN, *Yearbook of National Accounts* (various years), ECLA, *Statistical Yearbook for Latin America* (various years).

Table 7. *Public deficit* (as percentage of GDP, current)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	−3.0	−1.0	−1.4	−3.1	−2.0
Nicaragua	12/72	Eq	−2.4	−3.8	−1.8	−5.7	−5.6
Honduras	9/74	Hn	−2.7	−0.4	−0.9	−2.9	−2.5
Guatemala	2/76	Eq	−1.4	−0.8	−2.6	−0.9	−1.2
Domin. Rep.	9/79	Hn	0.0	−1.5	−5.8	−2.6	−2.5
Ecuador	11/82	Fd	−4.8	−4.4	−2.5	−0.8	2.0

Source: IMF, *Government Financial Statistics Yearbook* (various years), ECLA, *Statistical Yearbook for Latin America* (various years).
*The minus sign (−) indicates a deficit.

was in the second year of a modernizing and populist program of radical transformations, which appear to have speeded up with the disaster at least in the north of the country, where the disaster struck (Quijano, 1971). Similarly, Honduras was suffering from the boycott imposed by the multinational banana companies as a reaction against a higher tax on their exports, which both destroyed part of the production and declared low export figures so as to minimize the tax impact, at a time when the new oil prices were significantly affecting overall prices (see IMF, "Supplement of Economic Indicators" 1985). The disaster appears to have been exploited by the multinationals, for the government (and the tax) was removed by a new more compatible dictatorship a few month later, as indicated by Pierce (1981) and Dunkerly (1988).

Table 8. *Trade deficit** *(as percentage of imports)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	26	34	48	22	16
Nicaragua	12/72	Eq	−2	21	−15	−30	−22
Honduras	9/74	Hn	20	10	−23	−19	−6
Guatemala	2/76	Eq	−8	−5	−20	−7	−14
Domin. Rep.	9/79	Hn	−8	−21	−21	−17	−26
Ecuador	11/82	Fd	0+	0+	1	1	1

Source: IMF, *Balance of Payments Yearbook* (various years).
*The minus sign (−) indicates a deficit.

Table 9. *Trade deficit** *(per capita SDR)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	9	16	25	12	9
Nicaragua	12/72	Eq	−2	21	−21	−64	−42
Honduras	9/74	Hn	11	7	−25	−19	−6
Guatemala	2/76	Eq	−7	−4	−27	−11	−24
Domin. Rep.	9/79	Hn	−10	−24	−28	−49	−64
Ecuador	11/82	Fd	18	15	101	118	146

Source: IMF, *Balance of Payments Yearbook* (various years).
*The minus sign (−) indicates a deficit.

Table 10. *Reserve** *(per capita SDR)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	1	−3	−22	3	−2
Nicaragua	12/72	Eq	−3	−11	−26	12	−18
Honduras	9/74	Hn	−5	−2	5	−15	−11
Guatemala	2/76	Eq	2	−15	−28	−20	−3
Domin. Rep.	9/79	Hn	−5	6	−1	6	3
Ecuador	11/82	Fd	30	31	−15	3	5

Source: IMF, *Balance of Payments Yearbook* (various years).
*The minus sign (−) indicates an increase in reserves, i.e. a surplus in balance of payments.

Not surprisingly the GDP grew at unprecedented rates after the boycott was lifted (see Table 3 under t_2). The case of Ecuador, in turn, represents a country that was undergoing a continuous decline in its positive growth rates, from 5.9 in 1979 to 1.2 in 1982. In 1983, the year of the disaster in our account, the growth rate was negative (−3.1%). Clearly the disaster alone can hardly be the cause of that fall, basically because the disaster ratio is actually very small. The disaster could, however, have acted as a cofactor of ongoing negative economic forces, especially those that had made the investment ratio fall significantly in 1982, which cannot be attributed to the disaster. Despite being badly affected by the starting of the debt crisis, Ecuador was still committed to serve international duties (debt payments) against common sense, as indicated by the Central Bank of Ecuador (1991), probably representing an example of the fiscal constraint (see note 13). Nonetheless, any bad performance occurring in the 1980s, especially from 1982, is no

Table 11. *Capital flows* (per capita SDR)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	8	2	−8	−1	8
Nicaragua	12/72	Eq	24	3	55	103	84
Honduras	9/74	Hn	8	12	26	48	43
Guatemala	2/76	Eq	11	23	33	32	49
Domin. Rep.	9/79	Hn	23	40	34	83	55
Ecuador	11/82	Fd	73	10	−237	−119	−102

Source: IMF, *Balance of Payments Yearbook* (various years).
*The minus sign (−) indicates a net outflow of capital.

Table 12. *Unrequited transfers (per capita SDR)*

Country	Date	Event	t_{-2}	t_{-1}	t_0	t_1	t_2
Peru	3/70	Eq	3	2	6	3	3
Nicaragua	12/72	Eq	3	4	25	7	7
Honduras	9/74	Hn	2	2	9	5	4
Guatemala	2/76	Eq	7	10	27	13	14
Domin. Rep.	9/79	Hn	8	17	21	27	29
Ecuador	11/82	Fd	3	2	3	2	8

Source: IMF, *Balance of Payments Yearbook* (various years).

doubt primarily attributable to the "lost decade," as can be seen in Williamson (1990). This is also the reason why disasters after 1982 in Latin America were not considered. This, however, does not mean that cases after that date do not support the ensuing conclusions, such as the earthquake of Mexico in 1985, (ECLA, 1985), but that the analysis requires entering into the particular societal complications of that period, which is beyond the scope of this paper. Even in our sample there are already some important interferences unrelated to disaster such as the first oil shock. The cases of Nicaragua and Guatemala can probably be taken as purer and freer from major political and economic problems, as can be seen in Albala-Bertrand (1993).

From the above, it seems clear that if growth was foreign exchange constrained before the hazard, the disaster situation itself appears to have contributed to a relaxation of such a constraint, except in Honduras where there was a significant reserve loss. The fact that GDP growth rates were positively affected and that inflation did not accelerate in the countries in which the public deficit and/or GFCF increased significantly, serves as an important indication that underutilization of resources (especially labor) and/or fast maturity investments (e.g., fishing equipment) were available before the disaster, new foreign exchange availability being probably a factor helping their use after the disaster. This also indicates the operation of a multiplier of autonomous or exogenous expenditures. This exogeneity of expenditure is explained by both the need of a government to respond to disasters and the potential new investment and commercial opportunities created by a disaster, as indicated by Albala-Bertrand (1993), which can materialize if no other factors are constraining the economy (see also note 13). The two negative cases may also show the operation of negative multipliers under elastic expectation due to a pessimistic or depressive state of affairs, resulting in a response not sufficient to compensate for negative impact multipliers, unleashing both demand and cost inflation as output fell faster than aggregate demand.

For the application a number of assumptions has been made and some proxies have been used to represent the theoretical variables.[16] The results are presented in Table 12.

It can be seen that all actual growth rates move in the direction indicated by the comparison of Δe_1 with Δe_{a1}. That is, if $\Delta e_{a1} \geqslant \Delta e_1$ then $y_{a1} \geqslant y_{a0}$ and *vice versa*. In other words, if the variation

Table 13. *Required and actual total expenditure ratios and actual growth rates**

	Peru	Nicaragua	Honduras	Guatemala	Dom. Rep.	Ecuador
Date	3/70	12/72	9/74	2/76	9/79	11/82
Event	Eq	Eq	Hn	Eq	Hn	Fd
d	8	85	45	17	15	0.9
d_0	0.8	10	18	2	2	0.2
d_1	7.2	75	27	15	13	0.7
c	3.5	4.8	7.8	3.2	4.8	5.6
Δv_1	0.1	0.5	0.1	0.2	0.1	0.0+
Δv_{a1}	0.3	12.6	7.1	6.9	2.7	−8.1
$(1/2)d_0$	0.4	5.0	9.0	1.0	1.0	0.1
Δz_{a1}	0.9	−0.8	1.6	0.5	2.3	−1.8
Δe_1	0.5	5.7	9.2	1.2	1.1	0.1+
Δe_{a1}	1.2	11.8	8.7	7.4	5.0	−9.9
$\Delta e_{a1}/\Delta e_1$	>1	>1	<1	>1	>1	<1
y_{a0}	4.1	3.2	5.6	1.9	2.1	1.2
y_{a1}	7.3	6.4	−0.1	7.4	4.5	−3.1
y_{a1}/y_{a0}	>1	>1	<1	>1	>1	<1

Source: IMF, ECLA, UNESCO, UNDRO, CRIRZA.
d: total disaster loss ratio, d_0: current output loss ratio, d_1: capital loss ratio, c: uncorrected capital-output ratio, Δv_1: required variation of investment coefficient in the first year, Δe_1: total required variation of expenditure ratio in the first year (i.e. $\Delta v_1 + (1/2)d_0$), Δv_{a1}: actual variation of investment coefficient in the first year, Δz_{a1}: actual variation of government consumption ratio in the first year, Δe_{a1}: actual variation of total expenditure ratio in the first year (i.e. $\Delta v_{a1} + \Delta z_{a1}$), y_a: actual growth rate of GDP, "0": year before the impact, "1": year of the impact, Eq: earthquake, Hn: hurricane, Fd: flood.
Assumptions: $\alpha = \beta = \gamma = 2$, $\varepsilon = 0.8$, $\pi = 0.9$, $m = 2$ and $m_2 = 2m_1$. Notice that if $m_1 = m_2$ and/or $m = 1$ (no multiplying effect), the conclusions will still hold, see also note 13.

in the actual expenditure ratio is larger than or equal to the variation in the required expenditure ratio (equation 5.1), then we expect the growth rate to increase or at least not to fall in the first year after the impact, and *vice versa*. For example, for Guatemala's earthquake, given the basic data, the variation of the total expenditure ratio required for keeping the growth rate as if there were no disaster (i.e. Δe_1) is 1.2 percentage points. The actual variation of the total expenditure ratio (i.e. Δe_{a1}), however, was 7.4, implying that the actual growth rate in the first year should be larger than in the previous year. That was what actually happened. For Honduras's hurricane the case is reversed. The comparison between the required and the actual total expenditure ratios indicates that the growth rate should fall, as actually happened (see last four rows of Table 12). Therefore, the application appears to confirm the model.

5. CONCLUSIONS

The main conclusions can be stated as follows. First, the expected fall in the growth rate of output from disaster capital loss appears to represent only a small fraction of the ratio disaster loss-to-output, even before applying the more realistic corrections to both actual losses and the incremental capital-output ratio. Second, assuming reasonable values for all parameters, it can be shown that the total compensatory expenditure, and especially the minimum compensatory reconstruction investment, required to keep the level of output as if there were no disaster appears to be an even smaller fraction of the disaster loss ratio. This finding implies that the required reconstruction effort in any one year rarely needs to be large, even in the case of a very large natural disaster (i.e. very large ratio of direct disaster loss-to-output) — even less if emergency activities are taken to represent at least in part additional expenditure in the economy. Third, the reconstruction effort can be both moderate and spread over a number of years without negative effects on output. Finally, we showed within the indicated cautions that the model in general, albeit quite simple, appears to move close to actual disaster situations.

Taking into account potential responses at different levels of aggregation, especially endogenous responses (see glossary), the general conclusion is that exogenous responses (i.e. foreign and public) would be better aimed at helping directly the actual victims and affected activities than proceeding under the rather unsound *prima facie* belief that the economy will be heavily affected by the disaster.

NOTES

1. Official sources normally go along with newspapers' highly inflated "estimates" so as to both elicit a more generous international response and use the disaster as a scapegoat for normal government failings. See Albala-Bertrand (1993) and (1992a).

2. As indicated below in Rule I (see also glossary), the direct effect of a disaster impact is normally either geographically or economically localized (or both). Only in the case of widespread droughts in agriculturally undiversified developing countries (i.e. least-developed countries) the above rule may be violated. This may be the case of the droughts of the 1970s and again in the 1980s in some Sahelian African countries.

3. More by omission than statements, endogenous responses (see glossary), especially within the disaster area, are either rarely reported or not considered globally important. This is bound to create the impression that international or public earmarked aid is always insufficient, which is no doubt a distortion of reality. See Abril-Ojeda, (1992).

4. From this book, the statistical conclusion from the analysis of 28 cases of large localized natural disasters over 20 years can be set as rules. First, disaster situations do not make the level of GDP fall nor do they decrease the growth rate of GDP. If anything, there could be a short-term improvement in that rate. Second, the rate of inflation is not significantly stimulated by disasters. Third, gross fixed capital formation improves in the short term as does construction. Fourth, agriculture is not significantly affected by nonearthquake disasters. Fifth, the public deficit slightly increases. Sixth, the trade deficit sharply increases in the short term, but foreign reserves, capital inflow and, most of all, unrequited transfers (e.g., workers remittances, grants, etc.) all significantly increase over the short term, which means that the additional deficit is easily financed.

5. An intertemporal model may be more appropriate to deal with these flow effects, but the present model is still able to tackle both the effect of capital losses on growth and the required compensating expenditure, first by assuming that most indirect (flow) effects are endogenously counteracted via substitutions and second by applying the model intertemporally. The value of the parameters correcting the incremental capital-output ratio should be assessed according to the circumstance. Therefore, except for widespread droughts in agricultural, undiversified, developing countries (e.g., Sahelian countries), the use and the conclusions of the model may be largely appropriate, that is, for all cases where Rule I holds.

6. Incidental interference is the potential (and observed) outcome of the interaction of both the impact and the response with the structure and dynamics of the social system, which may catalyze or act as a cofactor of some important developments, e.g., introduction of new technology (e.g., Alaska's earthquake in 1964), political regime change (e.g., Ethiopia drought-induced famine in 1974), changes in demographic structure (e.g., normally in famines), and a variety of market reactions (new entrants, insertion into world markets, etc.). See Albala-Bertrand (1993).

7. These rules are the result of both a major survey and analysis of actual disaster situations. There actually are 11 significant rules, but as the other five are not required for the model, they are not presented here. See Albala-Bertrand (1993).

8. For what matters in this paper, the patterns establish that business fixed capital is not significantly affected by disasters (never more than 5% of total losses) and that the less-productive capital is more affected: first, residential capital; second, infrastructural capital; and then other types of fixed capital and inventories. See Albala-Bertrand (1993).

9. As endogenous and exogenous responses (see glossary) for emergency are well underway, the disarticulation of social frameworks, especially of the economic circuit, will not impose significant bottlenecks on economic flows. It should be also noted that this response activity is likely to succeed in the very short-term, i.e. one to two weeks. See Albala-Bertrand (1993) and (1992a).

10. For the earthquake of Guatemala in 1976, $d = 0.17$ and $c = 4.67$. See ECLA, "Danos Causados por el Terremoto de Guatemala" (1976) and Chenery (1979), respectively.

11. The multiplication of any aggregate loss (i.e. D, D_0, D_1, D_2, or D_3) by ε is assumed to correct the corresponding aggregate loss for overestimations.

12. It should be added that as the capital-output ratio theoretically represents a relationship between total capital and maximum potential output (i.e. a full employment relationship), if there was underutilization of resources across the board at the time of the disaster, then the effect of the capital loss on growth will be even smaller as not all that capital was being employed anyway.

13. In theory, a multiplier requires two conditions to operate: the existence of idle capacity and the opera-

tion of elastic expectations (i.e. any variation in demand is supposed to have some permanency). Capacity, especially in less-developed countries (LDCs), depends not only on plant and equipment availability but also on both labor availability, and labor-based productions (e.g., labor-based construction and other labor-intensive productions, if materials were available) and fast maturity investments (e.g., fishing equipment and commercial space, if demands — and goods — were available). A good deal of this potential capacity belongs to the informal sector, as seen in Thomas (1992). Excess demands can also be met with stocks and imports to ease capacity strain and hence potential inflation, but except for the value added from marketization, they do not add to GDP. At any rate, the value of the multiplier will be the nominal income increase per unit of additional exogenous expenditure, i.e. a mix of both real output and price increases per unit of additional exogenous expenditure. At one end, when the economy is at unconstrained full capacity, the value of the multiplier can only be the inflation it creates per unit of exogenous expenditure, as output cannot vary. At the other end, when the economy has enough unconstrained excess capacity, the value of the multiplier will be the value of the additional real output per unit of exogenous expenditure, if prices remain fixed. Therefore, the real multiplier can be defined as the nominal multiplier less inflation, i.e. the real output variation per unit of additional exogenous expenditure, which will be lower or equal to the nominal multiplier. For a lucid discussion of this, see Morishima (1980). In our application, the multiplier is taken in real terms, i.e. the additional real growth rate of GDP per unit of increase in investment (or expenditure) ratio. As will be seen, the fact that in the cases where there was an important additional expenditure there was also a higher real growth of GDP, and not necessarily a higher inflation rate, may be a clear indication of important underutilized capacity. At any rate, in LDCs, the level of underutilization of at least the labor force (the basis of any labor-based production, if materials were available) is normally several times that of open unemployment, and could reach on average around 30% of total labor force in LDCs, as indicated by Todaro (1989) and also Thomas (1992).

Most real economies, however, operate at levels normally well below full utilization of resources due to important institutional and structural constraints, e.g., shortages of foreign exchange and/or domestic savings, shortages of materials and capital (including human capital: skilled and managerial human resources), deficiency of infrastructures and communications, and general market imperfections and lack of information. Natural disasters normally relax some of these constraints. A two-gap model would indicate, on the one hand, that even if an economy was producing enough domestic savings, these might not be fully utilized due to lack of complementary capital goods, raw materials and skills, that can only be imported if sufficient foreign exchange was available, resulting in underemployment of domestic resources. This implies that additional exogenous expenditures may not unlock domestic resources unless accompanied by foreign exchange availability. Disasters usually provide important inflows of foreign exchange, as will be shown below, allowing a domestic multiplier to operate with less constraints. On the other hand, if there was enough foreign exchange, but not enough domestic savings to absorb it, the economy may operate with productively useless foreign exchange surpluses at least in the short and medium term. The fact that most of our cases normally operate with trade deficits and that significant (and well-financed) increases in the deficit occur after disasters may be an indication that there is no foreign exchange constraint and that foreign savings (i.e. the value of the deficit in trade and/or current account) are productively used. During 1975–82, this is highly likely to be true, regardless of disasters, given the banks' easy-loans policies derived from the abundance of petrodollar deposits, as shown in Fry (1988) and elsewhere.

There is, however, another important constraint, which a simple two-gap model does not take into account: even if there was no foreign exchange constraint, the level of savings might not be fully utilized if investment demand (i.e. an independent function from saving supply) is slackening. This is likely to depend on investment stimulants in both the private and the public sector. In the former, an important variable is likely to be the potential profitability of investment projects, which in turn depends on the availability of investment opportunities and expectations. Here again disasters appear as creating industrial and commercial opportunities that were either absent or locked before the disaster, especially as new needs and information on them becomes more readily available. In the case of government investment, if there was investment crowding-in (i.e. any unit of public investment has a positive effect on private investment due to both complementaries and market creation), which is highly likely as has been shown by many authors such as Taylor (1990) or Bacha (1990), and that investment expenditure can be stably financed, there will be a positive effect on both overall investment and output. The inability to undertake this expenditure is currently called the fiscal constraint or gap (especially due to services on the nationalized debt at the expense of investment) which adds to the other two constraints to speak of the three-gap analysis (see especially Taylor, 1991, chapter 8). Again, disasters create needs which may induce investment and expenditure opportunities for the government and the private sector which were absent before the event. Therefore, the multiplier of exogenous expenditures (i.e. the disaster being the exogenous factor that motivates both government responses and private "animal spirits," apart from foreign exchange support) is likely to operate more smoothly than it would have otherwise. It should be noticed that for the ensuing application to appear demonstrated, a real multiplier equal to (or even slightly smaller than) one (i.e. no multiplying or reducing effects) can still make valid all the conclusions.

14. To clarify, if the normal v was 20%, to compensate the economy fully for the expected loss in the growth rate of output, all other things being equal, v

will have to be 20.15, i.e. 0.15 percentage points more than otherwise it would have been.

15. It should be noted that public investment represents 20–40% of total investment. Likewise, statistics for domestic savings are both not readily available and highly unreliable as domestic savings are calculated as a residual. Therefore, tables for Construction and Gross Fixed Capital Formation as well as for the Trade Deficit are a more useful indication of the total savings effort.

16. First, only Latin American countries have been chosen because ECLA reports on the economic effects of disasters in Latin America are the only sufficiently systematic and reliable information and data available worldwide. Second, the incremental capital-output coefficients (ICORs) were calculated over the five-year period previous to the disaster year. Third, any variable with a subindex a_0 corresponds to the actual value of the variable in the year before the disaster, and any variable with a subindex a_1 corresponds to the year of the disaster. Fourth, anytime the disaster impact occurred in the last quarter of a year, the following year is taken as the disaster year. Strictly speaking it would have been more appropriate to calculate this latter variable one year after the impact, but there is no available quarterly, let alone monthly, data for the countries concerned. Fifth, the investment ratio (v) includes both gross fixed capital formation and variation of stocks and z is the ratio government consumption to GDP, used here as a proxy for noncapital autonomous expenditure. Sixth, the ratios in the disaster year (subindex a_1) are calculated with the GDP of the previous year, otherwise the variation would be over or underestimated, as the GDP also changes in the disaster year. Seventh, notice that by using gross rather than net investment the actual effect of capital expenditure may be overestimated. Finally we have used the same parameters for all countries, which may over or underestimate the actual effects. Even if impact and response multipliers, however, were of the same size and/or the real multiplying effect was equal to or just smaller than one (i.e. no multiplying or slightly reducing effect) all the conclusions will still hold, indicating that they do not primarily depend on the size of the multiplier.

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APPENDIX: GLOSSARY

Compensatory Investment Ratio: minimum required increase in the investment coefficient to compensate the economy fully for the expected decrease in the growth rate of output from capital loss.

Direct Disaster Effects:	as opposed to Indirect Disaster Effects, include all actual effects occurring as a direct result of the impact of an extreme natural event on a human settlement (i.e. destruction, damage, injuries and deaths), i.e. stock effects.
Disaster Impact:	as opposed to Disaster Response, is the actual interaction of an extreme natural event and a vulnerable human settlement (e.g., the collision of a hurricane on a coastal town).
Disaster Response:	as opposed to Disaster Impact, comprises all Endogenous and Exogenous reactions, actions, measures and policies to counteract, mitigate or prevent disasters.
Disaster Situation:	comprises Disaster Impact, Disaster Response and Incidental Interference as largely inseparable parts of an actual disaster event.
Disaster Size:	for economic purposes, it is determined by the size of the direct disaster loss-to-output ratio, a large disaster being that one that has a loss ratio of the size of the country's average growth rate, say 5%.
Emergency:	as distinct from Reconstruction, is the process of containment of Indirect Disaster Effects and of basic rearticulation of social frameworks. It comprises Relief (i.e. emergency actions on affected people) and Rehabilitation (i.e. emergency actions on the disarticulations of social frameworks).
Endogenous Response:	as opposed to Exogenous Response, is part of processes in-built in the social system. These processes react in a highly automatic fashion to compensate society for infrequent social or economic fluctuations (e.g., extended family, self-help, natural immunisation, market reactions, etc).
Exogenous Response:	as opposed to Endogenous Response, is set up as a result of *ad hoc* decisions. As such, it is nonautomatic and requires permanent supervision and control (e.g., grants, loans, foreign aid, tax relief, armed forces emergency activities, etc).
Human-Made Disaster:	as distinct from Natural Disaster, has a primary force which is societally (endogenously) unleashed, such as wars, riots, technological failures and depressions. It can, however, be catalyzed by a Natural Disaster as shown in Albala-Bertrand (1993).
Incidental Interference:	is the result of the interaction of both Disaster Impact and Disaster Response with society's structure and dynamics, which may catalyze significant changes.
Indirect Disaster Effects:	as distinct from Direct Disaster Effects, are all potential and actual effects resulting from the disarticulations of social frameworks, i.e. flow effects.
Localized Disaster:	is that which directly affects either a geographically confined part of the social system or an economically confined area of activity, or both. That is, a widespread drought (affecting the whole territory of a country) in a more diversified economy is considered as localized in this conception. By implication a localized disaster cannot directly affect the whole economy of a country. Localized disasters, therefore, represent the overwhelming majority of all disasters, large and small. The exception would be a widespread drought affecting an undiversified agricultural developing country (i.e. "least developed countries").
Natural Disaster:	as distinct from Human-Made Disaster, has a primary force induced by a Natural Event, although there could be interactions between the two types, as shown in Albala-Bertrand (1993).
Natural Event:	as opposed to Disaster, is any geophysical or biological event (e.g., earthquake, flood, plague, pest). It may originate a disaster only if it interacts with a vulnerable human settlement.
Reconstruction:	as distinct from Emergency, is the actual process of replacement of direct losses aimed theoretically at bringing the physical system back to its predisaster state.
Rehabilitation:	see Emergency.
Relief:	see Emergency.

Slowly Developing Disaster:	has a Disaster Impact of long duration and low or little noticeable immediate Direct Disaster Effects, e.g., droughts, epidemics, desertification.
Spread Period:	is the number of periods (months, years) over which Reconstruction can be spread without negative consequences for aggregate income (output). A series (series 4.4) can be generated by using the equation for the Compensatory Investment Ratio (equation 3.3).
Sudden Disaster:	has a Disaster Impact of short duration and immediately noticeable Direct Effects, e.g., earthquakes, floods, hurricanes, volcanoes.
Vulnerability:	is the exposure of society's physical frameworks, social groups and individuals to extreme events. In our context, it is a function of both available disaster-proof technology and societal processes which make people differentially at risk from given Natural Events (e.g., unsafe living quarters, unsafe activities).