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Disasters and Economic Welfare

Can National Savings Help Explain Post-disaster Changes in Consumption?

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Abstract

The debate on whether natural disasters cause significant macroeconomic impacts and indeed hinder development is ongoing. Most analyses along these lines have focused on impacts on gross domestic product. This paper looks beyond this standard national accounting aggregate, and examines whether traditional and alternative national savings measures combined with adjustments for the destruction of capital stocks may contribute to better explaining post-disaster changes in welfare as measured by changes in consumption expenditure. The author concludes that including disaster asset losses may help to better explain variations in post-disaster consumption, albeit almost exclusively for the group of low-income countries. The observed effect is rather small and in the range of a few percent of the explained variation. For low-income countries, capital stock and changes therein, such as forced by disaster shocks, seem to play a more important role than for higher-income economies, where human capital and technological progress become crucial. There are important data constraints and uncertainties, particularly regarding the quality of disaster loss data and the shares of capital stock losses therein. Another important challenge potentially biasing the results is the lack of data on alternative savings measures for many disaster-exposed lower-income countries and small island states.

This paper—a product of the Global Facility for Disaster Reduction and Recovery Unit, Sustainable Development Network—is part of a larger effort in Network to disseminate the emerging findings of the forthcoming joint World Bank-United Nations' Assessment of the Economics of Disaster Risk Reduction. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at mechler@iiasa.ac.at.

Disasters and Economic Welfare: Can National Savings Help Explain Post-disaster Changes in Consumption?

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1 POINT OF DEPARTURE

There is an ongoing debate on whether disasters cause significant macroeconomic impacts and are truly a potential impediment to development. A position backed by anecdotal evidence and a fair number of studies holds that natural disasters can set back economic development (Otero and Marti, 1995; Benson, 1997a,b,c; Benson and Clay, 1998, 2000, 2001; ECLAC, 1999, 2002; Murlidharan and Shah, 2001; Crowards, 2000; Charveriat, 2000; Mechler, 2004; Hochrainer, 2006; Cuaresma et al., 2008; Noy, 2009). Then, there is a position suggesting that disasters have no effects on economic growth (Albala-Bertrand, 1993, 2006; Skidmore and Toya, 2002; Caselli and Malhotra, 2004). Most analyses along these lines have focused on aggregate impacts, and here on GDP as the standard economic indicator for measuring changes in economic welfare. There is almost no work on other indicators of welfare, such as consumption, which in economics is usually taken as the basis for assessing changes in individual utility and social welfare. Furthermore, it is well known that GDP or GNI[2] are imperfect metrics for measuring changes in welfare, as those aggregates generally do not account for the depletion of natural resources, the value of household labor or investments in education. Several alternative concepts have been proposed, an important one being *genuine savings*,[3] which is an alternative welfare indicator based on concepts of green accounting (see, e.g., Hamilton and Atkinson, 2006). Genuine savings aims at better measuring the "true" national savings by adding investments in human capital and subtracting the consumption of capital stock, the depletion of natural resources and the adverse effects of air pollution. The validity of savings measures is commonly tested by studying their ability to explain variations in consumption changes. Although fraught with measurement problems, genuine savings has gained acceptance and found applications in research and policy. It is also standardly reported in the World Bank World Development Indicators.

In the context of natural disaster risk, an additional problem arises due to the fact that the destruction of assets (capital stocks) is not considered in national accounting (which essentially measures flows only), while the flow variables reconstruction and relief spending add positively to GDP, yet in fact only contribute to a recovery to a prior

[2] In the following, we use GNI, as savings measures in the WDI dataset are indicated as a share of this aggregate.
[3] In the WDI *genuine savings* are referred to as *adjusted savings.*

economic status quo. Thus, relief and reconstruction spending in fact have to be considered as a kind of "defensive spending," and consequently disaster losses may need to be adjusted for in national accounting statistics.

Given that disasters deplete capital stock and can be important in many countries, in this paper we examine and test whether disaster losses should also be appropriately considered in genuine savings and other savings measures.[4] Almost no work has been done on this issue. One paper, Barrito (2008), mentions this potential problem and suggests a way for revising wealth accounting, yet does not empirically test it.

Using a sample of large disaster losses over the 30 year period from 1971 to 2000, we examine whether factoring in such disaster shocks may help to better explain future variations in welfare as measured by private and public consumption expenditure. Overall we find some, albeit small and limited, evidence for adverse consequences of disasters on consumption. Focusing on alternative measures of welfare and assessing the contribution of disaster–related asset losses to changes in consumption, we conclude that accounting for disaster asset losses for disaster-exposed, low-income countries may help to better explain variations in post-disaster consumption and thus adjusting alternative welfare indicators (negatively) can lead to improved predictability of future post–disaster consumption changes.

The paper is organized as follows. We start in section 2 with introducing the concept of national savings and a proposal for deriving alternative savings measures. We further suggest considering disaster losses in savings measures and use a method to test the suitability of doing so. In section 3, we present results based on cross-country regressions for a sample of large-scale disasters. Section 4 ends with a discussion of these findings and implications of the analysis.

[4] There may also be an anticipatory effect as individuals adjust their savings and consumption decisions before or without an event, and thus baseline savings already incorporate part of the response to an event. Yet, generally, the literature finds people to be myopic faced with rare events such as disasters, and thus this effect may mostly be important in areas with frequent events, which are not considered in this dataset examining the largest 200 plus events over the last three decades.

2 Using and Applying Savings to Explain Changes in Consumption

In standard national accounting, gross national savings is calculated as the residual of income and consumption. Gross savings is the amount of annual gross income that is not consumed, and thus can be used for investment finally which adds to national wealth. Positive savings indicate an increment to overall national wealth. Standardly, national accounting only measures the increments to produced capital (or capital stock consisting of machinery, equipment, physical structures including infrastructure, and urban land area), yet social capital (human capital, quality of institutions, and the governance of goods and people) and environmental capital (land, forests and sub-soil resources) are not considered. Alternative savings measures have been proposed in order to also factor in investments in those capital classes, a key concept being that of genuine savings. Genuine savings can be derived from gross national savings, which is standardly reported in national accounting statistics, and four types of adjustments can be distinguished as suggested in World Bank (2006) as follows (see also figure 1):

(1) The depreciation of fixed capital representing the consumption of capital is deducted from gross savings leading to *net savings*.

(2) Current education expenditures representing investments in human capital (standardly, in national accounting these expenditures are considered a consumption item)[5] are added in order to obtain *net savings* plus education expenditure.

(3) The depletion of natural resources is factored in reflecting the decrease in the natural asset base due to the extraction and harvesting of resources leading to *genuine savings* excluding air and climate change damages.

(4) In a final step, social costs due to air pollution and climate change may be subtracted leading to an estimate of *genuine savings* including air and climate change damages.

[5] Although there is some discussion in the literature, which holds on the contrary that educational expenditure is closer to consumption than investment.

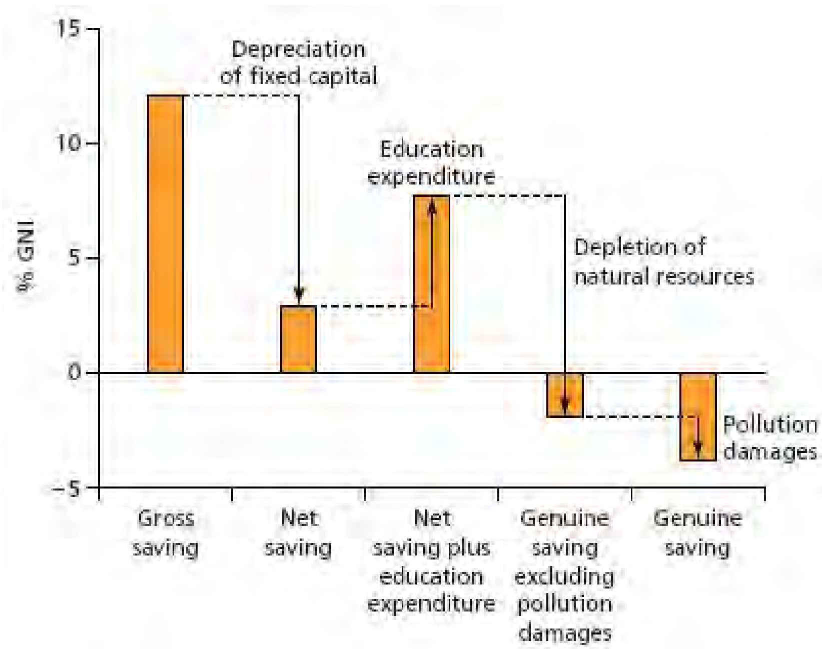

Fig. 1: Calculating genuine savings

Source: World Bank, 2006

Testing the explanatory power of savings

In order to test whether different savings concepts may indeed lead to an improved explanation of welfare changes, savings may be linked to consumption (see Dasgupta, 2001; Hamilton and Hartwick, 2005). In a competitive economy savings S (the increment to capital or wealth) in a given year t_o should equal the present value of changes in consumption ever after t_o, i.e., the future additional consumption produced thanks to the wealth increment. In equation form this can be expressed as follows:

$$\sum_{t=t_o+1}^{T} \frac{1}{(1+r)^t} \left(\frac{C_t}{N_t} - \frac{C_{t-1}}{N_{t-1}} \right) = S_{t_o}$$

with S, the savings measure, C consumption, N population, r discount rate, t time, and T end of the time horizon considered. Accordingly, this relationship may be tested empirically in a linear relationship as follows:

$$PV\ \Delta C_{t0+1,T} = \beta_0 + \beta_1 S_{t0} + \varepsilon_{t0}$$

with $PV\Delta C_{to+1,T}$ the present value of the change in per capita consumption from year t_o+1 to T, and S the respective savings measure in t_0, and $\beta_{0,1}$ the coefficients and error term ε. In order to account for demographic change, tests should derive per capita estimates.[6]

Disaster adjusting savings

It seems intuitive to think about including disaster losses in genuine and others savings measures. Overall, there may be two (interlinked) channels through which disasters and associated losses may impact on future consumption: (1) by directly destroying capital stock, output and income is decreased, depressing future consumption, which is generally a function of income, (2) due to the need for rebuilding assets and livelihoods, planned consumption is foregone in favor of reinvestments. Both channels seem important, yet here we focus mostly on channel (1) and test whether capital accumulation and associated future consumption opportunities are affected.

Disasters have the potential to cause substantial direct and indirect losses and destroy a large portion of produced capital. Over the last 30 years, there have been about 50 instances where losses exceeded 10% of gross national product (GNP), another 50 events where losses ranged from 5-10% of GNP, and about 110 events with losses exceeding 1% GNP. It is important to note that most of the very large events affected Small Island States, or smaller, lower-income countries - countries small enough to have their entire territory affected by one event, or countries too economically limited as to be able to absorb the losses as very roughly proxied by GDP (such as observed for St. Lucia by Hurricane Gilbert in 1988) (see figure 2).

[6] Ferreira et al. (2008) conduct a more in depth assessment of the savings measure accounting for population dynamics and omitted wealth. Yet, they find their results to only marginally improve, so we do not consider these additional factors in the following.

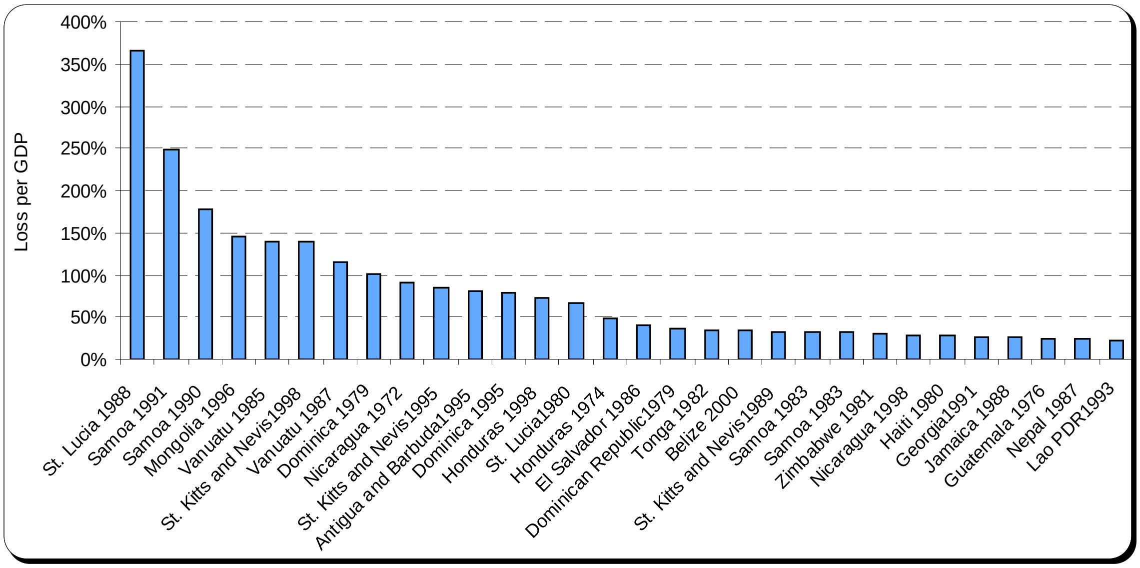

Fig. 2: 30 largest monetary disaster losses since 1970
Source: own calculations based on data by EMDAT (CRED, 2009); Munich Re, 2008.

Although only a part of these losses are in fact capital stock losses, it seems evident that losing a substantial portion of produced assets will impact the capital accumulation process, affect produced wealth and as a consequence impair income creation. Barrito (2008) suggests that, if factoring in reported disaster losses as the stock losses, capital accumulation may fall significantly and permanently short of regularly reported increments to capital (see Figure 3). Consequently, capital accumulation in vulnerable countries such as El Salvador, Fiji and St. Lucia may be strongly affected by one or multiple events whereas in large and diversified economies no significant effect may be identified.

Given a lower capital accumulation path, it is straightforward to expect adverse welfare effects, such as changes in consumption and consumption volatility over time. The key question we pursue in this paper is to assess whether natural disaster losses can be considered to affect consumption and whether including them in savings measures may help to improve the predictive power of savings constructs. Our entry point is to adjust for disasters by adding the disaster related depreciation in terms of losses of capital stock to the other regular depreciation of capital.

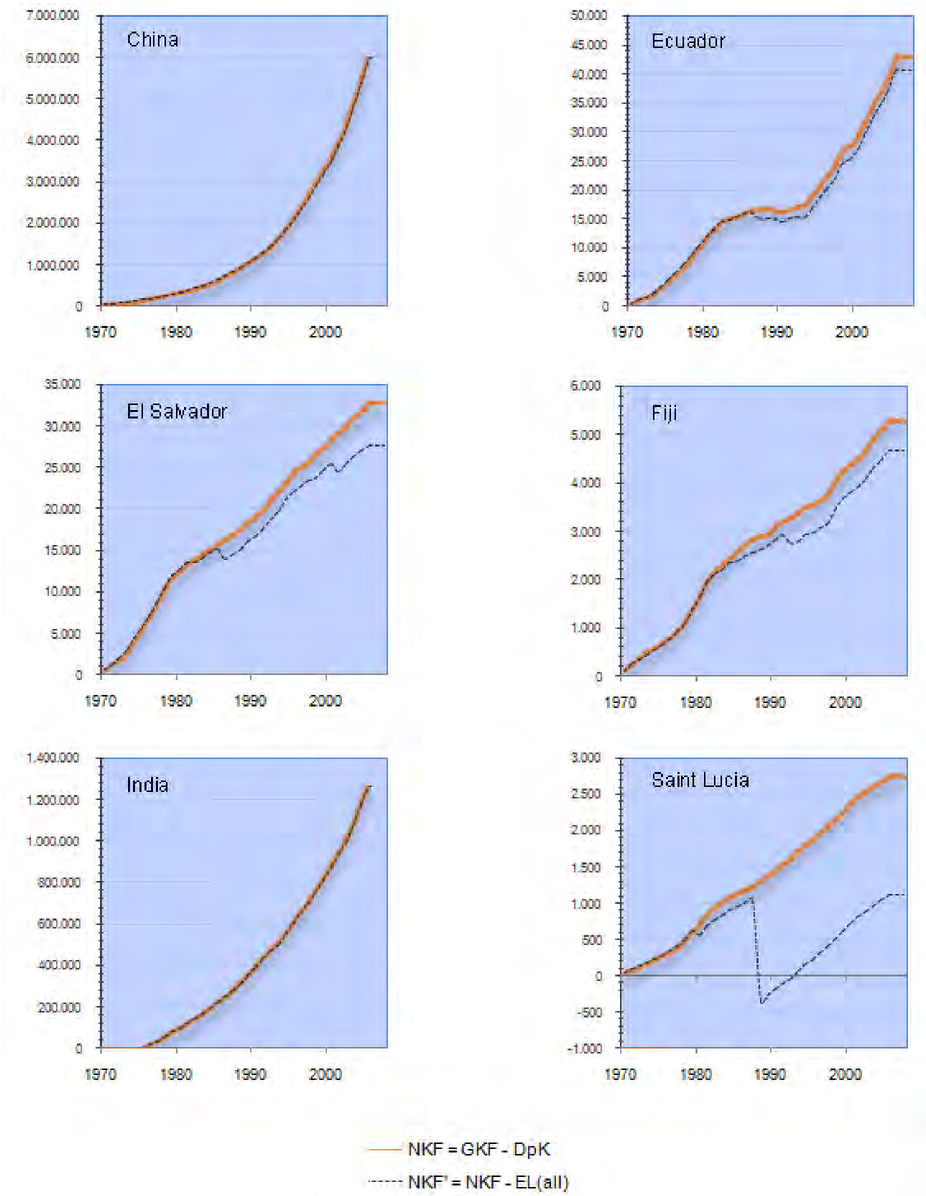

Fig. 3: Capital accumulation and disaster-related capital depletion

Note: In millions of constant 2000 USD; NKF = Net Capital Formation; NKF’ = Net Capital Formation adjusted by disaster losses. GKF=Gross Capital Formation; DpK = Depreciation of capital; EL (all) = Monetary disaster losses.

Source: Barrito, 2008.

A question is which savings measure to choose. A recent study by Ferreira, Hamilton, and Vincent (2008) using panel data for 64 developing countries during the period 1970–82 for different savings adjustments finds that the key step in such analysis is to account for the depletion of natural resources, which leads to a significant improvement in the relationship of savings and changes in consumption. The authors contend that genuine savings are most meaningful if adjustments have been made for natural resource depletion.[7] We use this savings measure and further adjust it by subtracting disaster asset losses in the given event, and in order to compare also examine gross and net savings, overall leading to three disaster adjusted savings indicators: (i) gross disaster savings, (ii) net disaster savings, and (iii) genuine disaster savings. We compare these constructs to the savings measures unadjusted for disaster losses. The intuition behind the adjustment is to include the adjustment of capital stock losses resulting from an exogenous disaster shock. In line with World Bank (2006), we conduct standard bivariate regression and do not simultaneously account for other explanatory variables beyond savings measures. Yet, we compose subsamples, such as differentiated by country income groups.

Data and estimation procedure

The analysis is based on observed and calculated savings and the present value of consumption per capita from the disaster year into the future up to 2005, the last year with rather complete information (in constant 2000 USD values). As savings are likely to be affected in the event year, as discussed above, we use reported savings in the year before the event and adjust this for the disaster asset loss, then start with calculating the consumption change in the year of the event up to 2005, the last year of our time horizon. Savings and consumption are reported as per cent of GNI of the year before the event. In fact, this approach is equivalent to assuming that the event happened right at the start of the disaster year.[8] The global disaster sample initially consisted of 168 large natural disaster events during the period 1971-2005, for which about 7,900 events are recorded overall. The sample is based on information from two databases and was compiled by Okuyama (2009) with the threshold for a large event defined arbitrarily by a loss exceeding 1 percent of GDP.[9] One database is the open-source EMDAT database (CRED, 2009) maintained by the Centre for Research on the Epidemiology of Disasters at the Université Catholique de Louvain. EMDAT currently lists information on people

[7] Pollution damage in terms of health effects of air pollution may be factored in a next step as well, yet such inclusion does not add to our discussion here, and thus is omitted here, also as there are generally even more data constraints.

[8] This holds mostly for sudden onset disasters which are instantaneous events occurring over minutes and hours, whereas droughts have a lead in of weeks to months.

[9] In order to define the "event set" the threshold of stock losses is set as a share (1%) of flow effects (GDP). It would have been more systematic to define an asset based threshold, yet we responded to the larger intuitive appeal of using GDP as a denominator, and the fact that this threshold was also used by other papers in the EDRR working paper series, which we wanted to be in line with.

killed, made homeless, affected and financial losses for more than 16,000 sudden-onset (such as floods, storms, earthquakes) and slow-onset (drought) events from 1900 to the present. Data are generally collected from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. The other database is the proprietary Munich Re NatCat Service database, which mainly serves to inform insurance and reinsurance pricing. This database contains fewer entries focusing on the about 300 largest events since 1950, yet data exhibit a higher reliability as they are often crosschecked with other information. We focus on the monetary losses listed in constant 2000 USD terms. In both datasets, loss data follow no uniform definition and are collected for different purposes such as assessing donor needs for relief and reconstruction, assessing potential impacts on economic aggregates and defining insurance losses (see Provention, 2002). The sample comprises of sudden and slow onset events. Key sudden-onset events are extreme geophysical events (earthquakes) and hydrometeorological events such as tropical cyclones, floods and winterstorms. Slow-onset hydrometeorological disasters are either of a periodically recurrent or permanent nature; these are mostly droughts, extreme temperature events and forest fires. Table 1 classifies the events in our sample according to cause and type of event.

Table 1: Classification of events in sample

Hazard	**Cause**	**Type**
Flood	Hydrometeorological	Sudden onset
Storm	Hydrometeorological	Sudden onset
Mass movement wet	Hydrometeorological	Sudden onset
Drought	Hydrometeorological	Slow onset
Extreme temperature	Hydrometeorological	Slow onset
Wildfire	Hydrometeorological	Slow onset
Earthquake	Geophysical	Sudden onset

Loss data may refer to direct and indirect loss, or stocks and flows, in unknown proportions. As for our analysis only the direct stock losses are of importance, we resort to assumptions and refer to evidence on the share of the direct capital stock losses in productive sectors and infrastructure in different events in Latin America, for which good information was at hand. Based on information listed on Table 2 and Table I-2 in the Appendix for which a simple average would amount to 33%, given uncertainty around this parameter, we finally take the simplifying assumption of using a share of 35% stock losses in reported total losses.[10]

Table 2: Portion of total loss considered as direct, capital stock loss based on country cases

Event	Capital stock losses (productive sector and infrastructure) as a share of total loss
Hurricane Stan in El Salvador, 2005	36%
Hurricane Stan in Guatemala, 2005	30%
Hurricane Mitch in Honduras 1998	48%
Hurricane Mitch in Nicaragua 1998	29%
Earthquake in El Salvador, 2001	21%
Arithmetic Average	33%
Parameter used in this study	**35%**

Sources: ECLAC 1999, 2002; Telford et al., 2004; CRED, 2009

For the savings measures and socio-economic information, we use World Bank Development Indicators (World Bank, 2009) for calculating consumption, gross, net and genuine savings and GNI per capita.[11] The discount rate used for discounting future consumption was 5% for all series (in line with World Bank, 2006).[12]

Table 3: Overview over data used

Variable	**Data source**	**Time horizon**
Disaster losses (USD)	EMDAT, Munich Re	1971-2000
Consumption (USD)	WDI 2009	1970-2005
Gross National Income, GNI (USD)	WDI 2009	1970-2005
Population	WDI 2009	1970-2005
Gross savings (% of GNI)	WDI 2009	1970-2005
Net savings (% of GNI)	WDI 2009	1970-2005
Genuine savings (% of GNI)	WDI 2009	1970-2005
Aid (% GNI)	WDI 2009	1970-2005
GDP deflator[13]	WDI 2009	1970-2005
Country income groups	WDI 2009	2005

[10] Varying this parameter within reasonable bounds did not importantly affect the analysis.
[11] Note, those data were indicated as a share of GNI, not GDP, so the analysis is based on GNI.
[12] Conducting sensitivity analysis with discount rates related to country income groups, we find the discount rate to be relatively insensitive to marginal changes, yet, an extension of this work might explore using country-specific discount rates.
[13] In the absence of a GNI deflator, we used the GDP deflator.

We restrict our analysis to events as late as the year 2000, so that a minimum of 5 years of consumption data can still be used. As discussed in Ferreira, Hamilton, and Vincent (2008), green accounting theory refers to an infinite time horizon, and it has been shown that results become more valid with a longer time horizon; other studies have used a minimum of 10 years, with a preference for 20 years. In contrast, we use a minimum of 5 years, yet in order to maintain a large number of observations, we keep the time horizon flexible from a minimum of 5 to a maximum of 33 years of consumption changes observed. We do find this flexibility in terms of time horizon to adversely affect the analysis, which we discuss in the following. Given the data and adjustments done and a lack of net and genuine savings data for a number of countries, only 99 observations remained. Importantly, many of the low income countries with massive losses (such as the biggest event of St. Lucia in 1988) dropped out due to a lack of savings or consumption data, which is a constraint of the analysis to keep in mind. Table 4 quantitatively describes the key variables used for the analysis.

Table 4: Descriptive statistics for the whole sample (N=99)

	Minimum	**Maximum**	**Mean**	**Std. Deviation**
Time horizon (years)	5	33	15.1	8.18
Loss	-0.57	-0.01	-0.04	0.08
Gross savings	-0.04	0.56	0.17	0.12
Gross disaster savings	-0.25	0.54	0.13	0.14
Net savings	-0.14	0.45	0.08	0.11
Net disaster savings	-0.33	0.44	0.04	0.13
Genuine savings	-0.32	0.38	0.07	0.12
Genuine disaster savings	-0.42	0.37	0.02	0.14
PV ΔConsumption	-0.44	1.04	0.18	0.24

Losses exhibit a wide range from 1% to 57% of GNI per capita of the year of the event. The means of the (non-disaster adjusted) savings variables seem broadly of similar magnitude as the present value of consumption changes with means of 0.17, 0.08 and 0.07 of GNI as compared to the average consumption change of 0.18% of GNI per capita. The “disaster” adjustment to the savings indicators reduces the means and increases variability as measured by the standard deviation. To provide an idea for the distribution behind the summary statistics reported in Table 4, Figure 4 shows gross savings and gross disaster savings across the 99 cases. We observe that in the majority of cases adjustments are small to moderate with a few very large events leading to severe disaster-related dissavings.

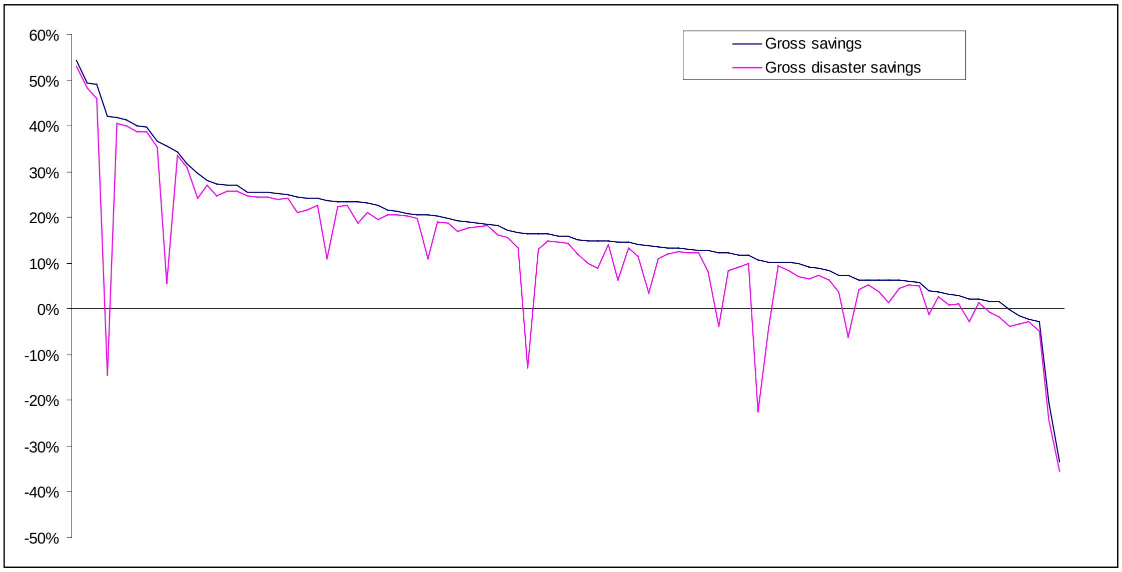

Fig. 4: Gross and gross disaster savings for the whole sample (as a share of GNI in the year before the event)

A key issue to consider is the effect of aid (and aid volatility) on consumption. The question whether aid leads to higher investments (and thus to higher consumption in the future), or is simply consumed, is of course at the heart of the development discourse and there is no overall consensus (see, e.g. Arellano et al, 2009). This issue seems particularly important for our analysis, as generally in large scale disasters additional aid in terms of relief and reconstruction assistance is received. For example, in earlier work (Freeman et al., 2002), based on a regression analysis of large-scale disaster events, we find that about 10% of losses in larger events will be compensated by relief and reconstruction assistance. In order to revise for this "muddying" effect of international aid, particularly for the case of lower-income countries, we also calculate scenarios, where we subtract aid from consumption. In order to generally illustrate the calculation procedure, below we outline the case of Honduras, which experienced four large events (1974, 1982, 1990 and 1998) over the time horizon of our study.

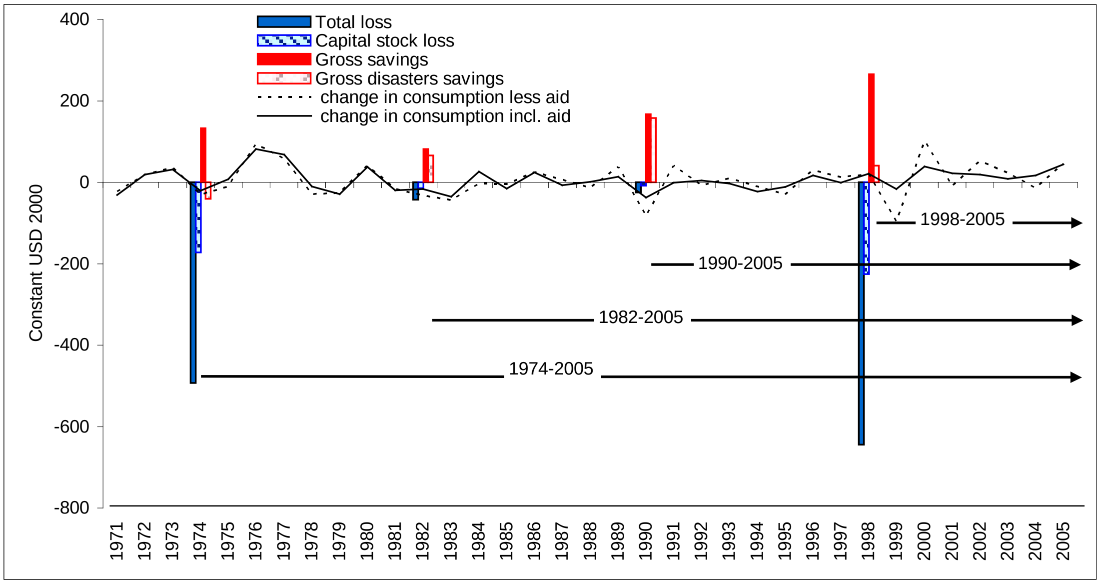

Fig. 5: Disaster losses and changes in consumption in Honduras with and without aid

Note: Values in 2000 constant USD per capita.

In Honduras, we observe multiple events leading to total and capital stock losses; beyond the ones we look at in our sample with the 1% threshold, there are another 35 events of smaller magnitude over the time horizon studied listed in the EMDAT database. Disasters seem to have led to decreases in consumption spending in the year of and following events (also depending on whether catastrophes happened early or late in a given year). Aid seemingly has had a smoothing effect, and consumption generally exhibited some volatility due to other reasons (for example, the hyperinflation in the 1990s). The chart also shows the varying time horizons adopted in this study for examining effects on consumption changes over time.

3 FINDINGS

For our sample of 99 events, we start out with assessing whether asset losses can be said to affect the present value of post-disaster consumption changes. As shown on Table 5 for the whole sample and for two further samples for which we report results further below, all hydrometeorological events and hydrometeorological events in the low-income group of countries, the loss is highly insignificant (this is also the case for all further regressions undertaken), and the (nonstandardized) coefficient is positive, which is counterintuitive, yet may be explained by the fact that there are many other perturbations affecting consumption positively as well as negatively, and thus the loss alone might have little effect on future consumption.

Table 5: Regression losses on consumption changes for different samples

Model	Whole sample (N=99)	Sudden hydrometeorological events (N=62)	Sudden hydrometeorological events, low income group (N=35)
	PV dConsumption in per cent of per capita income of the year before the event		
Constant	0.188***	0.175***	0.152**
	(7.028)	(4.582)	(2.526)
Loss	0.206	0.083	0.345
	(0.677)	(0.150)	(0.365)
R Square	0.005	0.001	0.004

Note: Significance at the * 10% level;** 5% level; *** 1% level

Focusing on the savings measures in a next step, we first assess how the savings measures explain consumption changes irrespective of disaster adjustments (table 6).

Table 6: Regression results for the whole sample (N=99)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dConsumption in per cent of per capita income of the year before the event					
Constant	0.061	0.104***	0.124***	0.155***	0.137***	0.166***
	(1.59)	(3.42)	(4.40)	(6.54)	(5.17)	(7.17)
Savings measures	0.692***	0.585***	0.654***	0.560***	0.621***	0.518***
	(3.78)	(3.67)	(3.28)	(3.25)	(3.04)	(2.99)
R Square	0.129	0.122	0.100	0.098	0.087	0.085

Note: Significance at the * 10% level;** 5% level; *** 1% level

The savings variables are all significant and most of the constants similarly so. Further, for the whole sample, the size of these values is in line with findings from other studies with about 13%, 10%, and 9% of the consumption change explained by gross, net and genuine savings measures respectively in the baseline year. To provide some perspective, Hamilton and colleagues in World Bank (2006) find that gross savings and genuine savings explain about 15% resp. 24% of the variation in consumption using consecutive 20-year periods. Coefficients are of the right order of magnitude (ideally they should be 1) ranging from 0.7 to 0.6 compared to a range of 0.4 to 1.3 reported in World Bank

(2006). What is not in line with the literature is the fact that the explanatory power decreases when going from gross to net to genuine savings. This can be explained by the flexible time horizon chosen out of necessity to keep the number of observations as large as possible. For example, as shown on table 7, when adopting a fixed 15 year time horizon, thus "losing" 56 observations, the R square actually doubles for genuine savings. Also, constants become unimportant and genuine savings very significant at the 1% level. We suggest to keep this limitation in mind, yet in order to assess interesting subsamples in the following, we propose to continue working with the variable time horizon given our small dataset of 99 observations only. Accordingly, the analysis should not be understood as shedding more light on the debate whether genuine savings better explain consumption changes, but rather whether disaster "depreciation" helps improve the explanatory power of savings measures generally.

Table 7: Regression results for the fixed time horizon of 15 years (N=43)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dConsumption in per cent of per capita income of the year before the event					
Constant	0.001	0.027	0.035	0.055**	0.044*	0.070***
	(0.029)	(0.957)	(1.328)	(2.315)	(1.931)	(2.998)
Savings measure	0.437*	0.344**	0.470*	0.374*	0.670***	0.556***
	(1.948)	(1.807)	(1.836)	(1.732)	(2.897)	(2.717)
R Square	0.085	0.074	0.076	0.068	0.170	0.153

Note: Significance at the * 10% level;** 5% level; *** 1% level

Yet, overall, deducting disasters does not improve the explained variation, and R squares actually decrease slightly for both specifications and all savings measures, so, for the sample looking at all hazard types and income classes we do not find disaster depreciation to better explain regressions.

We now further test different subsamples, such as for sudden, slow onset and sudden hydrometeorological events separately. As can be seen on Table II-1 in the Appendix, the sudden onset group had similar explanatory power in terms of R squares as the whole dataset, while for genuine savings the R square measure as indicator of the explained variation now actually slightly improved when introducing disaster losses. Then, as shown on Table II-2 for the slow-onset events (while probably too small for robust results with only 21 observations), all variables become insignificant indicating that indeed slow onset events may largely lead to indirect, flow losses rather than to direct, stock impacts to be explained by savings measures. As a next sample, sudden–onset, hydrometeorological events (storms and floods) are examined leading to the strongest results in terms of R squares (from 0.33 to 0.19), while also the disaster adjustment decreases the quality of the regression. A factor explaining this difference in results is clearly that most of the earthquakes (13 out of 15) in the sample occurred in high and medium income countries, while many low income countries in the sample are prone to massive flooding and storms (hurricanes). Thus it seems to be income, further discussed below, which picks up most of the explained variation. We do not feel confident going beyond this in trying to explain the variation by the types of sudden onset events.

Overall, we find for the sample undifferentiated by per capita income that revising savings for disaster shocks does not reliably improve regression results in terms of better explaining post-disaster consumption variation.

Low and middle-income sample

As a next step, we further divide the sample into country groups differentiated by per capita income with the expectation that the explanatory power of savings may increase as we zoom into the group of medium to low-income countries, where capital stock should become more important.[14,15] Generally, work on genuine savings has contended that in developing countries, produced capital due to its sheer scarcity is a more important component of wealth than in higher-income countries, where human capital seems more critical (see, e.g., Ferreira et al., 2008). Also, as discussed above, for this group of developing countries, aid inflows play an important role, and we further test the effect of subtracting normal and disaster-related aid inflows from consumption. Table 8 shows that all variables remain significant at the 1% level, while R squares substantially increase to, e.g., 0.33 for gross savings. Also, the size of the coefficients in four instances increases above 1. Yet, adding in capital stock losses does not help with explaining consumption

[14] We did not separately examine the middle and high income samples due to the limited sample sizes.

[15] Classification is also dynamic, as countries may change their income status, yet none of the countries analyzed in this group did leave the low to middle income group.

changes and actually diminish the quality of the regression (e.g., from 33% to 28% explained variation for gross savings).

Table 8: Regression results for the low and middle income sample, sudden hydrometeorological events (N=62)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dConsumption in per cent of per capita income of the year before the event					
Constant	-0.031	0.041	0.061*	0.120 ***	0.075 **	0.124 ***
	0.67	(1.07)	(1.79)	(4.03)	(2.01)	(3.95)
Savings measures	1.214 ***	1.014 ***	1.229 ***	0.995 ***	1.109 ***	0.974 ***
	(5.33)	(4.74)	(5.05)	(4.42)	(3.96)	(3.71)
R Square	0.325	0.276	0.302	0.249	0.210	0.189

Note: Significance at the * 10% level;** 5% level; *** 1% level

We also analyze the effect of revising for aid by subtracting aid from consumption (see Table 9), and results do not change substantially, neither for the unadjusted nor genuine savings indicators, indicating that regular and post event aid in this sample does not lead to substantial changes in welfare post-disaster.

Table 9: Regression results for the low and middle income sample, sudden hydrometeorological events revised for aid (N=62)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dConsumption in per cent of per capita income of the year before the event					
Constant	-0.047	0.026	0.052	0.112***	0.067*	0.116***
	1.02	(0.68)	(1.49)	(3.69)	(1.76)	(3.63)
Savings measures	1.283***	1.086***	1.269***	1.044***	1.133***	1.016***
	(5.53)	(5.00)	(5.07)	(4.53)	(3.92)	(3.76)
R Square	0.338	0.295	0.300	0.255	0.204	0.191

Note: Significance at the * 10% level;** 5% level; *** 1% level

Low-income group

Finally, we turn to assessing events in low-income countries only. As expected, this produces the best results in terms of explaining consumption changes by savings measures. Table 10 reports sample information for the group of sudden hydrometeorological events.

Table 10: Model results for the low income sample, sudden hydrometeorological events (N=35)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dConsumption in per cent of per capita income of the year before the event					
Constant	-0.094	-0.043	-0.001	0.046	0.042	0.073
	(1.522)	0.817	0.027	(1.043)	(0.741)	(1.500)
Savings measures	1.414***	1.403***	1.434***	1.471***	1.148***	1.323***
	4.894	(5.028)	(4.474)	(4.736)	(2.827)	(3.228)
R Square	0.421	0.434	0.378	0.405	0.195	0.240

Note: Significance at the * 10% level;** 5% level; *** 1% level

To start with, while the savings measures are all highly significant, coefficients increase to above 1. Overall, the statistically explained variation also increases substantially to, e.g., a R square of 0.42 for gross savings. Then, most interestingly, the disaster adjustment finally makes a difference and the explained variation increases by about 1%, 2.5% and 4.5% for gross savings, net savings and genuine savings, respectively. Best results are still obtained when using the conventional gross savings measure. Further revising for aid inflows improves regression results slightly and increments in explanatory power are 3%, 4% and 5.5% respectively (see table II-4). It is important to remember that due to a lack of genuine savings and consumption data, a number of highly vulnerable countries, such as disaster-prone Caribbean countries (e.g., St. Lucia, which in 1988 experienced the largest ever loss as compared to national income) are not considered in this data set, which may improve the results in terms of explained variation with and without accounting for disaster shocks.

We tentatively conclude that for this group of low-income countries and events, produced capital, and thus losses therein, play a stronger role in explaining consumption changes; furthermore, disasters losses seem to have a small adverse impact on consumption streams, although the disaster loss variable is again highly non-significant. To provide a graphical impression of these relationships, on Figure 6, we chart out gross disaster savings vs. the present value of changes in consumption for this sample.

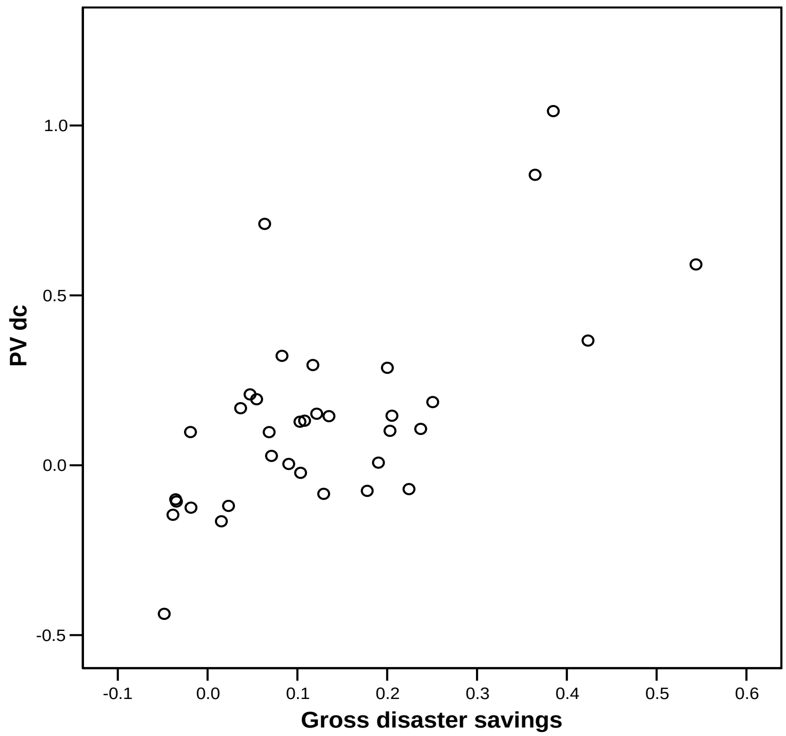

Fig. 6: Gross disaster savings vs. the change in consumption for the low income sample, sudden hydrometeorological events (as a share of GNI)

Further focusing in on this sample, such as separately studying flood and storm events, is not reliably possible, as, e.g., only 20 flood, 13 storm and two wet mass movement events remain for this income group.

4 DISCUSSION AND IMPLICATIONS OF THE RESEARCH FINDINGS

There is an ongoing debate on whether disasters cause significant macroeconomic impacts and are truly a potential impediment to economic development. The discussion is almost exclusively focused on impacts on GDP. We suggested that, as disasters, *inter alia*, destroy capital stocks, there may be important medium-longer-term welfare effects in terms of consumption opportunities foregone as a consequence of reduced produced capital accumulation. Taking a longer term perspective (5 up to 33 years after an event) we examined welfare changes in consumption potentially caused by the loss of capital stock; we hypothesized that, if indeed those existed, national savings measures adjusted for disaster asset losses should better explain changes in post-disaster consumption streams.

Overall, we tentatively conclude that adjusting savings for disaster effects helps in better explaining post-disaster changes in welfare, yet mostly for the low-income group of countries. Furthermore, the estimated effect is rather small. For the whole sample, and the combined medium and low-income groups, disaster capital stock loss adjustments to savings does not reliably lead to improvements in explaining post-disaster consumption changes. Also, losses by themselves do not significantly explain changes in consumption, probably due to the small size of the effect and the many other pressures on consumption. Furthermore, sudden onset events, and here floods and storms, perform best which can be attributed to the fact that sudden onset events predominantly destroy assets, whereas slow onset events such as droughts or extreme temperature incidences rather lead to longer term indirect effects, which are not well picked up by the savings measure focusing on accounting for investments into capital stock. Furthermore, switching from gross savings to genuine savings mostly does not improve results in this regard. This result, somewhat at odds with theory and empirical work, can be explained by the flexible time horizon adopted. When using the fixed 15-year time horizon, indeed genuine savings measures better explain the consumption changes than gross and net savings do. Accordingly, our analysis is not to be understood as aiming to shed more light on the debate whether genuine savings better explain consumption changes, but rather whether adjusting disaster "depreciation" helps improve the explanatory power of savings measures generally.

An implication of our work may be that accounting for disaster asset losses in savings measures for disaster-exposed, low-income countries may help better explain variations in post-disaster consumption changes and thus adjusting alternative welfare indicators (negatively) leads to improved predictability of future post–disaster consumption changes. For some highly disaster exposed and vulnerable countries it may be worthwhile to explore using such further refined measures when planning policy, also given the increasing availability of country-wide risk estimates and savings indicators.

Overall, however, we have to acknowledge the small size of the sample and the fact that data exhibit important constraints hindering us to reasonably go beyond tentative conclusions. A key bottleneck has been the limited number of observations, mainly due to a lack of genuine savings data for a number of highly vulnerable countries, such as for many disaster-prone Caribbean countries (e.g., St. Lucia, which in 1988 experienced the largest ever loss as compared to national income). This lack of data for countries expected to be particularly vulnerable to natural hazards may have lead to an important bias in the analysis. Consequently, we might expect our findings to improve if more observations are added. Constructing a more comprehensive and detailed database of disaster losses and savings measures may help to some extent with better addressing this problem, yet, by definition, the study of extreme events will always be constrained by scarce and imprecise data.

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APPENDIX I: ADDITIONAL DATA AND INFORMATION

Table I-1: List of countries, events, losses and country characteristics (N=99)

Country	year	Income group	Type	Loss % GNI_{t-1}
Algeria	1980	M	Earthquake	-0.03
Armenia	1997	M	Earthquake	-0.007
Armenia	2000	M	Drought	-0.018
Australia	1974	H	Flood	-0.008
Australia	1981	H	Drought	-0.011
Bangladesh	1974	L	Flood	-0.022
Bangladesh	1987	L	Flood	-0.011
Bangladesh	1988	L	Flood	-0.027
Bangladesh	1991	L	Storm	-0.032
Bangladesh	1995	L	Storm	-0.007
Bangladesh	1998	L	Flood	-0.033
Belize	2000	M	Storm	-0.135
Bolivia	1982	L	Flood	-0.037
Bolivia	1983	L	Drought	-0.05
Bolivia	1983	L	Drought	-0.06
Bolivia	1992	L	Mass movement wet	-0.026
Cambodia	2000	L	Flood	-0.015
Canada	1977	H	Drought	-0.005
Chile	1985	M	Earthquake	-0.021
China	1991	L	Flood	-0.012
China	1993	L	Flood	-0.008
China	1994	L	Drought	-0.01
China	1996	L	Flood	-0.013
China	1998	L	Flood	-0.011
Colombia	1999	M	Earthquake	-0.007
Costa Rica	1996	M	Flood	-0.007
Czech Republic	1997	M	Flood	-0.012
Dominica	1989	M	Storm	-0.045
Dominica	1995	M	Storm	-0.295
Dominica	1995	M	Storm	-0.034
Dominican Republic	1979	M	Storm	-0.127
Dominican Republic	1998	M	Storm	-0.047
Ecuador	1987	M	Earthquake	-0.034
Ecuador	1993	M	Mass movement wet	-0.015
Egypt, Arab Rep.	1992	M	Earthquake	-0.01
El Salvador	1982	M	Flood	-0.027
El Salvador	1986	M	Earthquake	-0.142
El Salvador	1998	M	Storm	-0.012
Fiji	1993	M	Storm	-0.026

Georgia	2000	M	Drought	-0.02
Guatemala	1976	M	Earthquake	-0.095
Guatemala	1998	M	Storm	-0.015
Haiti	1994	L	Storm	-0.009
Haiti	1998	L	Storm	-0.019
Honduras	1974	L	Storm	-0.162
Honduras	1982	L	Storm	-0.012
Honduras	1990	L	Flood	-0.008
Honduras	1998	L	Storm	-0.303
Hungary	1986	M	Drought	-0.009
Hungary	1992	M	Drought	-0.005
India	1993	L	Flood	-0.008
Indonesia	1997	M	Wildfire	-0.012
Iran, Islamic Rep.	1999	M	Drought	-0.01
Japan	1995	H	Earthquake	-0.008
Jordan	1992	M	Extreme temperature	-0.033
Macedonia, FYR	1995	M	Flood	-0.032
Madagascar	1977	L	Storm	-0.049
Madagascar	1981	L	Storm	-0.019
Madagascar	1982	L	Storm	-0.021
Madagascar	1984	L	Storm	-0.024
Madagascar	1986	L	Storm	-0.016
Mauritania	1979	L	Drought	-0.016
Mauritius	1989	M	Storm	-0.01
Mauritius	1994	M	Storm	-0.014
Mauritius	1999	M	Drought	-0.014
Mexico	1985	M	Earthquake	-0.009
Moldova	1997	M	Flood	-0.008
Moldova	2000	M	Storm	-0.006
Mongolia	1990	L	Wildfire	-0.011
Mongolia	1996	L	Wildfire	-0.567
Mongolia	2000	L	Storm	-0.027
Morocco	1999	M	Drought	-0.009
Mozambique	1990	L	Drought	-0.007
Mozambique	2000	L	Flood	-0.036
Nepal	1980	L	Earthquake	-0.04
Nepal	1987	L	Flood	-0.082
Nepal	1988	L	Earthquake	-0.026
Nepal	1993	L	Flood	-0.017
Nicaragua	1972	M	Earthquake	-0.332
Nicaragua	1982	M	Storm	-0.052
Nicaragua	1988	M	Storm	-0.039
Nicaragua	1991	M	Wildfire	-0.02
Nicaragua	1998	M	Storm	-0.104

Pakistan	1973	L	Flood	-0.019
Pakistan	1976	L	Flood	-0.015
Pakistan	1992	L	Flood	-0.007
Philippines	1972	M	Flood	-0.012
Philippines	1990	M	Earthquake	-0.008
Poland	1997	M	Flood	-0.009
Senegal	1976	L	Drought	-0.053
Sri Lanka	1978	M	Storm	-0.007
Sri Lanka	1992	M	Flood	-0.01
Swaziland	1984	M	Storm	-0.03
Tajikistan	1992	L	Flood	-0.053
Tajikistan	1993	L	Mass movement wet	-0.026
Tajikistan	1998	L	Flood	-0.024
Tajikistan	2000	L	Drought	-0.019
Turkey	1999	M	Earthquake	-0.02
Venezuela, RB	1999	M	Flood	-0.014

Table I-2 Information on direct, indirect and capital stock losses for selected disaster events

Hurricane Stan in El Salvador, 2005 (million USD)	Losses		
Sector	Direct	Indirect	Total
Social (housing, education, health)	48	102	150
Productive (agriculture, industry, commerce, tourism)	22	34	56
Infrastructure (water and sanitation, electricity, transport)	106	8	114
Environment	21	1	22
Emergency and relief expenditure		11	11
Total (ECLAC)	196	145	352
Total loss according to EMDAT			356
Capital stock losses (productive sector and infrastructure) as a share of total loss	36%		
Capital stock losses (productive sector and infrastructure) as a share of total loss (EMDAT)	**36%**		
Hurricane Stan in Guatemala, 2005 (million Quetzales)	Losses		
Sector	Direct	Indirect	Total
Social (housing, education, health)	630	543	1,173
Productive (agriculture, industry, commerce, tourism)	306	1,736	2,042
Infrastructure (water and sanitation, electricity, transport)	1,960	1,437	3,396
Environment	308	...	308
Emergency and relief expenditure		595	595
Total (ECLAC)	3,203	3,716	7,514
Total loss according to EMDAT			7,542
Capital stock losses (productive sector and infrastructure) as a share of total loss	30%		
Capital stock losses (productive sector and infrastructure) as a share of total loss (EMDAT)	**30%**		
Hurricane Mitch in Honduras 1998 (million USD)	Losses		
Sector	Direct	Indirect	Total
Social (housing, education, health)	305	719	1,024
Productive (agriculture, industry, commerce, tourism)	1,478	577	2,055
Infrastructure (water and sanitation, electricity, transport)	348	164	512
Environment	47	0	47
Emergency and relief expenditure		156	156
Total (ECLAC)	2,178	1,460	3,794
Total loss according to EMDAT			3,794
Capital stock losses (productive sector and infrastructure) as a share of total loss	48%		
Capital stock losses (productive sector and infrastructure) as a share of total loss (EMDAT)	**48%**		

Table I-2 Direct, indirect and capital stock losses for selected disaster events (continued)

Hurricane Mitch in Nicaragua 1998 (million USD)	Losses		
Sector	Direct	Indirect	Total
Social (housing, education, health)	225	45	270
Productive (agriculture, industry, commerce, tourism)	128	57	185
Infrastructure (water and sanitation, electricity, transport)	159	147	306
Environment	na	Na	-
Emergency and relief expenditure		227	227
Total (ECLAC)	512	249	988
Total loss according to EMDAT			988
Capital stock losses (productive sector and infrastructure) as a share of total loss	29%		
Capital stock losses (productive sector and infrastructure) as a share of total loss (EMDAT)	**29%**		
Earthquake in El Salvador, 2001 (million USD)	Losses		
Sector	Direct	Indirect	Total
Social (housing, education, health)	496	120	616
Productive (agriculture, industry, commerce, tourism)	244	96	340
Infrastructure (water and sanitation, electricity, transport)	97	375	472
Environment	102	1	103
Emergency and relief expenditure		73	73
Total (ECLAC)	939	591	1,604
Total loss according to EMDAT			1,500
Capital stock losses (productive sector and infrastructure) as a share of total loss	21%		
Capital stock losses (productive sector and infrastructure) as a share of total loss (EMDAT)	23%		

Sources: ECLAC, 1999, 2002; Telford et al., 2004; CRED, 2009

APPENDIX II: FURTHER RESULTS OF THE REGRESSION ANALYSIS

Table II-1 Regression results for the sudden onset events (N=77)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dconsumption in per cent of per capita income of the year before the event					
Constant	0.050	0.096***	0.114***	0.147***	0.127***	0.154***
	(1.13)	(2.73)	(3.48)	(5.36)	(3.90)	(5.62)
Savings measures	0.730***	0.606***	0.689***	0.571***	0.614**	0.561**
	(3.40)	(3.27)	(3.00)	(2.92)	(2.45)	(2.57)
R Square	0.133	0.125	0.107	0.102	0.074	0.081

Note: Significance at the * 10% level;** 5% level;   *** 1% level

Table II-2 Regression results for the slow onset event sample (N=21)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dConsumption in per cent of per capita income of the year before the event					
Constant	0.097	0.131*	0.156**	0.182***	0.172***	0.204***
	(1.17)	(1.99)	(2.60)	(3.58)	(3.50)	(4.24)
Savings measures	0.577	0.515	0.552	0.537	0.729*	0.494
	(1.56)	(1.56)	(1.29)	(1.38)	(2.00)	(1.68)
R Square	0.113	0.113	0.081	0.091	0.174	0.129

Note: Significance at the * 10% level;** 5% level;   *** 1% level

Table II-3 Regression results for the sudden-onset, hydrometeorological events sample (N=62)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dConsumption in per cent of per capita income of the year before the event					
Constant	-0.031	0.041	0.061*	0.120***	0.075**	0.124***
	0.67	(1.07)	(1.79)	(4.03)	(2.01)	(3.95)
Savings measures	1.214***	1.014***	1.229***	0.995***	1.109***	0.974***
	(5.33)	(4.74)	(5.05)	(4.42)	(3.96)	(3.71)
R Square	0.325	0.276	0.302	0.249	0.210	0.189

Note: Significance at the * 10% level;** 5% level; *** 1% level

Table II-4 Regression results for the low income sample, sudden hydrometeorological events revised for aid (N=35)

Model	Gross savings	Gross disaster savings	Net savings	Net disaster savings	Genuine savings	Genuine disaster savings
	PV dConsumption in per cent of per capita income of the year before the event					
Constant	-0.112*	-0.063	-0.013	0.033	0.033	0.062
	1.77	1.17	0.25	(0.73)	(0.55)	(1.22)
Savings measures	1.472***	1.483***	1.461***	1.526***	1.155***	1.369***
	(4.94)	(5.21)	(4.36)	(4.75)	(2.73)	(3.23)
R Square	0.425	0.452	0.366	0.406	0.184	0.240

Note: Significance at the * 10% level;** 5% level; *** 1% level