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Macroeconomics of natural disasters
Meta-analysis and policy options

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Abstract

We use the case of the macroeconomic impact of natural disasters to analyse strengths and weaknesses of meta-analysis in an emerging research field. Macroeconomists have published on this issue since 2002 (we identified 22 studies to date). The results of the studies are contradictory and therefore the need to synthesize the available research is evident. Meta-analysis is a useful method in this field. First, we observe many methodological differences in terms of heterogeneity in the data sources, the samples (country coverage and research period), the econometric specifications and the estimation procedures. We use meta-analysis both to identify the extent of heterogeneity and its potential impact and to find out research needs. Second, in this emerging scientific field the findings are preliminary and often contradictory due to the scientific process of finding out the 'true' effect. Meta-analysis can be used to distil this effect that often cannot be observed on the basis of individual studies. Third, as meta-analysis provides a transparent and objective way to synthesize research, this tool is useful in an area that like natural disasters impact is vulnerable to bias due to the ideological or intrinsic motivation of the researcher.

An important aim of our paper is to show how one can use the identified methodological characteristics to better understand the significance of future findings. Understanding the robustness and importance of new findings is crucial because they influence policy decisions with a potentially long-run impact, especially since both prevention and mitigation require investments over considerable periods of time. The second aim is to find out what are the most important research needs from the perspective of the emerging literature. We identify strengths and weaknesses in terms of coverage and robustness of control variables showing gaps in the literature and highlighting the importance of some rigour in the phase of reporting results and, for example, suggest that it is necessary to include population and institutions more often among the control variables.

We also provide a case study on the IPCC's special report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* in order to contrast the meta-analysis and its findings with an influential traditional review of literature (that also comprises qualitative research).

The two methods force two different perspectives on researchers and each perspective helps to uncover other (aspects of) literatures. Our conclusion is that research synthesis would benefit from combining the two approaches. A meta-analysis without a traditional review of the literature is incomplete.

Keywords

Meta-analysis; natural disasters, growth, resilience, policy.

Macroeconomics of natural disasters[1]
Meta-analysis and policy options

1 Introduction

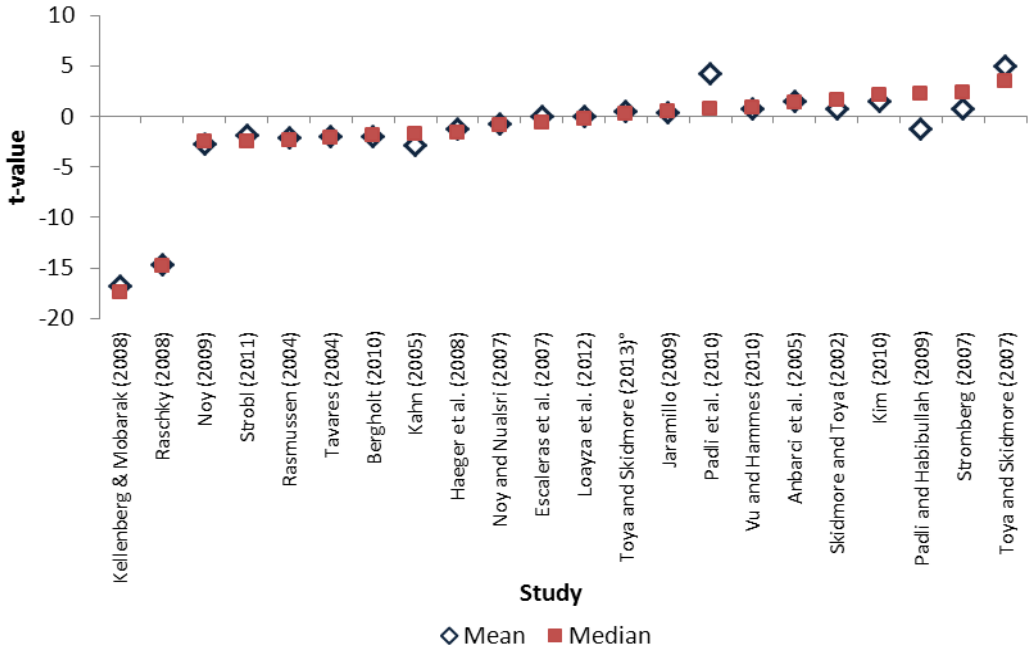
The macroeconomic analysis of natural disasters is a fairly recent branch of economic research (Okuyama, 2007; Pelling et al., 2002). Traditionally this topic was mainly investigated by other disciplines of social sciences and the technical sciences (Cavallo & Noy, 2010). In as far as economics was involved the analysis was typically of a microeconomic and/or case-specific nature. Macroeconomists became involved because of both the higher frequency and higher intensity of natural disasters and also as a consequence of their relation to global warming. Accordingly, the empirical literature on the macroeconomic impact of natural disasters has grown substantially (Raschky, 2008; see also Figure 1). We have identified 22 macroeconomic studies in the last decade that empirically assess the effects of natural disasters (Lazzaroni & van Bergeijk, 2013). We identified these 22 studies in an extensive search using Econlit and Google Scholar and using broad keyword listings with the following terminologies: 'natural disasters', 'impact', 'growth', 'economic development', 'development', 'killed', 'affected', 'institutions'.[2] We will refer to these 22 studies as the primary studies. Of these 22 studies 2 studies (Padli et al. 2009 and Jaramillo 2009) could not be included because key statistical characteristics were not reported in the primary study. So in this paper we consider 20 primary studies from which we collected 658 parameter estimates and methodological characteristics for each of the primary studies and the individual regressions reported in these studies. The macroeconometric analyses focus on the effects of series of natural disasters and could be interpreted as investigating their 'mean' costs (Hallegatte & Przyluski, 2010). According to the ECLAC methodology, costs from disasters can be classified into three categories (Zapata-Marti, 1997: 10-11 and Hallegatte & Przyluski, 2010): (a) the direct costs that occur at the moment of the event (damages to

[1] This working paper by necessity is partly based on Lazzaroni and van Bergeijk (2013) and was prepared for presentation at the Harvard Center for Risk Analysis workshop, "Methods for Research Synthesis: A Cross-Disciplinary Approach." (October 3-4, 2013; see http://www.hsph.harvard.edu/hcra/research-synthesis-project/) Preliminary versions were presented at the annual MAER-Net colloquium (Greenwich, September 2013) and the International Summer School on Environment and Resource Economics: Frontiers in Economics of Natural Hazards and Disaster Risk Reduction - Financing Disaster Risk Reduction and Climate Change Adaptation (Belpasso, September 2013).

[2] Literature reviews were not included in our meta-analysis. Since we are interested in collecting t-statistics of the variables considered, empirical works using vector autoregressive models, input-output and computable general equilibrium (CGE) analyses could not be included since the former reported the impulse response functions only and not the short and long-term coefficients while the results of input-output and CGE analyses by design do not provide the standard errors or t-values that we need in our meta-analysis.

assets, goods and services losses of lives or number of people affected by the disaster); (b) the indirect costs (decreases in flows of goods, services and business revenues due to destructions and/or business interruptions); and (c) secondary effects (changes in the performance of the overall economy). Half of the primary studies deal with direct costs and the other half deal with indirect secondary costs.

FIGURE 1
Empirical studies on the macroeconomic impact of disasters (median and average reported t statistics in 22 studies for the impact of disasters on (in)direct costs)



Source: Lazzaroni and Van Bergeijk, 2013, Table 1.

Figure 1 reports the median and average t-value of each study for the association between disaster and macroeconomic impact. One of the key messages of Figure 1 is that the findings of the available economic studies tend to disagree regarding this fundamental relationship given the large divergence for both the sign and the statistical significance of the impact of natural disasters. The average t-value in our sample is -0.9 with a standard deviation of 5.9. The median is -0.8 with a stand deviation of 4.9.

The disagreement between the studies is also apparent at deeper levels of analysis, for example when we analyse the 22 studies reported in Figure 1 with respect to whether they deal with indirect or direct costs. The median t-coefficient with respect to the ability of certain factors to mitigate disaster direct costs is positive in 9 cases and negative in 2 studies suggesting a positive association. When the studies analyse the impact of disasters on GDP the median t-statistic is positive in 4 cases and negative in 7 cases suggesting a negative association.

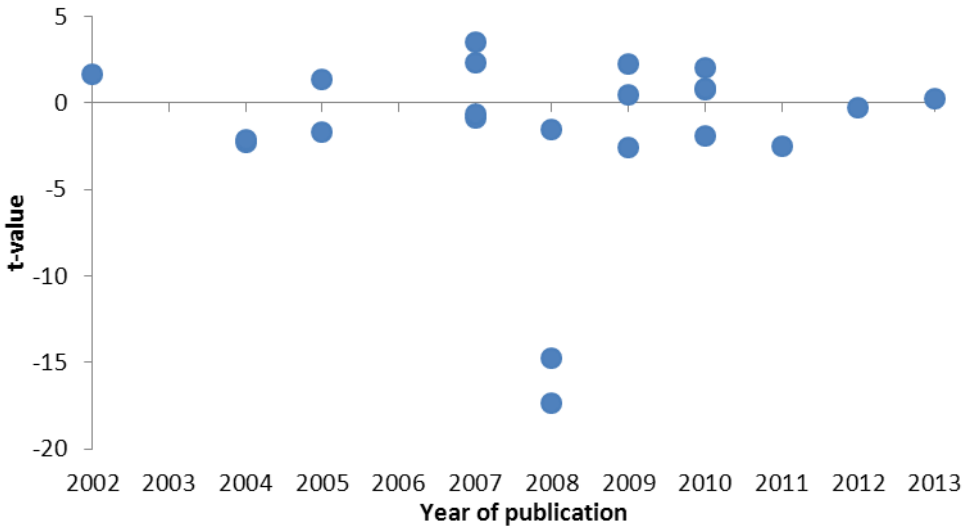
2 Why meta-analysis?

This paper takes stock of the emerging literature on the macroeconomics of natural disasters, not only because of the relevance of the topic of the macroeconomics of natural disasters, but also in order to discuss the use of meta-analysis as a tool to synthesize knowledge in an emerging and politically sensitive field. The latter is important because of the apparent disagreement between the studies in our sample. Meta-analysis is a research method that enables to synthesize and summarize previously obtained empirical findings for a research question in a quantitative and statistically rigorous fashion and to present the results of several studies in a coherent framework and also to estimate an average or meta-effect across studies (Florax et al., 2002). We use a somewhat broader approach and also provide descriptive statistics of several aspects of the literature so as to quantify and qualify results of the body of primary studies. The bibliometric aspects of the literature may help to identify differences in the frequency with which methodologies have been applied as well as the need to interact and extend sets of explanatory variables covered by the literature. From the start it is clear that the disagreement between the primary studies in our sample may be caused by several sources.

1. **Methodological differences**
   Behind the disagreement may be heterogeneity in the data sources, the samples (country coverage and research period), the econometric specifications and the estimation procedures. In such a context a meta-analysis of the reported results can be used to shed light on the impact that the methodology exerts on the results reported in the primary studies. Meta-analysis thus allows one to identify which methodological treats are associated with finding a specific result (in our case we have four results: a significantly negative; a negative; a positive; and a significantly positive sign of the association).
2. **Preliminary state of findings**
   In the case of the macroeconomics of natural disasters the meta-analysis is extra useful because, as in any emerging scientific field, the findings are preliminary and often contradictory due to the process of finding out the true effect. Figure 2 illustrates this process for our case as it plots the median t-value per study and relates this to the year of publication. Starting with Skidmore and Toya (2002) and ending with Skidmore and Toya (2013) the eye-o-metrician sees a cyclical pattern. This pattern emerges, because typically the scientific debate on new issues is characterized by independent replications (both based on the original data set of the primary study and on alternative data sets and samples), updates (when more data become available because new events occur) and innovations (of models and tests) that all may result in alternative findings. A clear example of this process is the replication study made by Reed and Mercer (2013) of the study by Toya and Skidmore (2007). Reed and Mercer update and extend the disaster data and perform a number of robustness checks to tackle

truncation bias and skewedness of disaster data, introduce country and time fixed effects and cluster standard errors. Contrary to the original study by Toya and Skidmore, Reed and Mercer find that economic development variables (income, educational attainment, size of the government, openness and financial sector development) are generally speaking not significant.[3] Typically many such contradictions emerge during the years in which a new scientific field emerges. Meta-analysis is a tool that can be used to distil a common trend or overall finding from the findings of the primary studies as well as measures of statistical confidence and accuracy and also and importantly to find out which methodological differences may be behind the apparent disagreement.

FIGURE 2
Median t-values of the primary studies 2002-2013



Source: see Figure 1.

3. **Intrinsic motivation and bias of the researchers**
Climate change is an important topic with substantial societal and political relevance, and therefore researchers may be driven by idealistic or ideological motivations to report those results that fit their conceptions of the importance of the problem, the need to find solutions as well as the kind of instruments that should be used and may ignore other results (compare Doucouliagos and Paldam 2009 on development aid). A meta-analysis is more objective and transparent than the traditional review of literature because it enables the researcher to systematically study the sources of variation in the quantitative results reported in the primary studies.

[3] The only reportedly significant effect is that natural disasters trigger larger economic losses for wealthier countries.

In this paper our goal is not primarily to find out the 'true' meta-effect that could be derived from the contradicting studies (compare DeCicca and Kenkel 2013), but instead to disentangle the impact of methodological choices in the primary studies and the policy consequences that those choices could have. As we do not analyse the coefficients that have been estimated in the primary studies but rather the sign and significance of those coefficients as represented by their t-values, we are unable to arrive at the precise and exact parameter values that are often necessary to populate economic models (Betranou and Mallender, 2013). It is, however, important to note that sign and significance provide very basic and relevant information for policy purposes especially in the context of benefit-cost analyses. Clearly increasing an instrument can logically only be cost effective if a related instrument variable is negatively associated with disaster costs (so that it reduces its impact). In this sense our meta-analysis points out if a necessary condition is fulfilled.

Our first aim is to show how one can use these methodological characteristics to better understand the significance of new findings. For example, as will become clear later on, studies that use an alternative to the commonly used EM-DAT data set (such as Anbarci et al. 2005; Escaleras et al. 2007; Skidmore and Toya 2002; Strobl 2011) are more likely to find a significantly negative t-value. If a new study that uses an alternative data source would find a significantly negative t-value that would in a qualitative sense constitute more convincing evidence. Understanding the robustness and significance of new findings is an important issue because due to the different findings, the policy recipes that follow or could be derived from those studies differ. Cost-benefit analyses of preventive measures and mitigation will be influenced by the findings. For example, Hallegatte (2012) assessing the potential benefits from upgrading hydro-meteorological information production and early warning capacity in all developing countries finds that these measures could reduce disaster losses through a reduction of asset losses between 300 million and 2 billion USD per year in developing countries. Hallegatte argues that these benefits should increase with growth, in line with the findings of the macro-econometric study by Toya and Skidmore (2007). Since both prevention and mitigation require investments over considerable periods of time, wrong decision based on (a selection of) the early literature will have a substantial long-run impact.[4]

The second aim is to find out what the most important research needs from the perspective of the emerging literature would be. To stay with the example of alternative data sets. If the meta-analysis clarifies that the choice of the data set is important and that relatively few studies use alternative data, then the conclusion would be that the development and exploration of alternative data sets is important for future research.

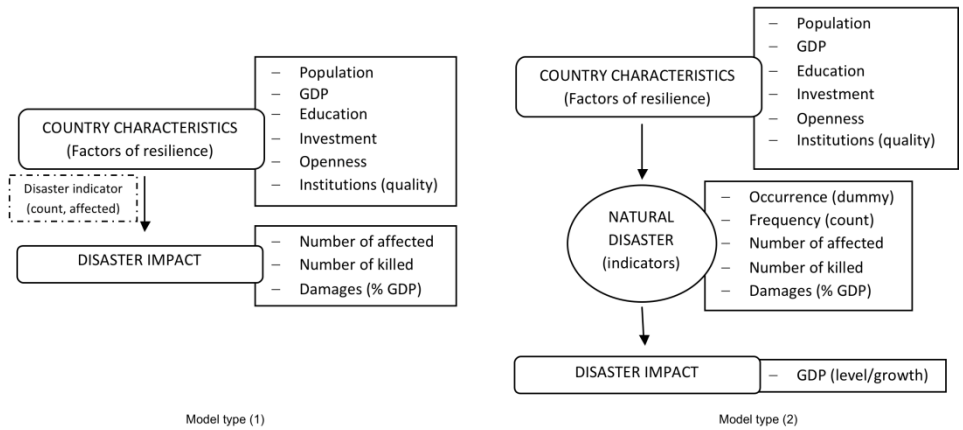
[4] Note however that cost-benefit analyses on disaster prevention measures (relying on means) should be considered somehow inappropriate due to the fat tails in the probability distribution of the likelihood of catastrophic event scenarios (Noy, 2012).

3 Literature review: two methodologies of the macroeconomics of disasters

The methodology of the primary studies shows many and obvious similarities basically because all studies in our sample deal with the macroeconomics of disasters from multi-country and/or multi-event perspectives (Cavallo & Noy, 2010). Behind these similarities important differences exist, however, as the empirical literature can be subdivided into two groups on the basis of the key variable of interest. These two bodies of literature study two variables that are both fundamentally different but are also on their own merits relevant for policy.

The first variable is the direct costs, typically quantified by disaster damages, economic losses, number of people affected and/or casualties. The second variable is the indirect cost that identifies the second order economic effect of natural disasters on GDP; this effect is indirect because it is based on the (estimated) impact of destruction of the capital stock, loss of labour force and a reduction of actual working and production days.

DIAGRAM 1
Two model types that study the macroeconomic impact of natural disasters



Source: Lazzaroni & van Bergeijk, 2013, Figure 1.

It is useful to distinguish these two approaches (Diagram 1). The first approach (Model type 1) tries to understand how socio-economic factors influence the effects of disasters focusing on the direct costs of disasters. Model type 1 studies consider only periods in which disasters actually occurred, avoiding the need of a 'disaster variable' in the equation.[5] The second approach (Model type 2) focuses on the impact of natural disasters on GDP using a specific 'disaster variable' that accounts for the occurrence of the

[5] Only a few studies account for the frequency or severity of the disaster (Kahn, 2005; Kellenberg & Mobarak, 2008; Raschky, 2008; Rasmussen, 2004).

phenomenon. The disaster variable can be a dummy, a disaster frequency or a variable describing the number of people affected or killed or the damages reported in case the disaster occurred (direct costs). Hence the variables accounting for number of affected or killed and damages are a disaster impact variable in model type (1) and a disaster indicator in model type (2). The two models use common sets of explanatory variables.

While fundamentally different, the direct and indirect impact studies are at the same time of course highly interrelated (Pelling et al., 2002: 285), not only in the minds of the producers[6], but also in the mind of the users of the research findings as will become clear below in our case study of IPCC (2012). Importantly, both approaches offer potentially important contributions to assess the potential utility of policy interventions and aim to help design and shape future policies targeted at disaster mitigation. Unfortunately, however, the studies offer contradictory advice. For example, Kahn (2005) suggests that more democratic countries experience lower death counts and Escaleras et al. (2007) and Raschky (2008) report similar results when accounting for corruption and government, respectively. In contradistinction, Strömberg (2007) and Skidmore & Toya (2013) report a negative but non-significant effect of increasing democracy and political rights and a positive but non-significant effect of civil liberties levels. Similar contradictions can be observed with respect to other potentially mitigating factors, such as education and openness.

Figure 3 takes a closer look and illustrates the extent of disagreement by classifying the *t*-values reported in 447 equations in 20 studies on the economic impact of disasters that use the direct and indirect costs approach, respectively. The figure reports the percentage share of significant coefficients in the total of reported coefficients for the specific strand of literature. Figure 3 allows us to make three observations.

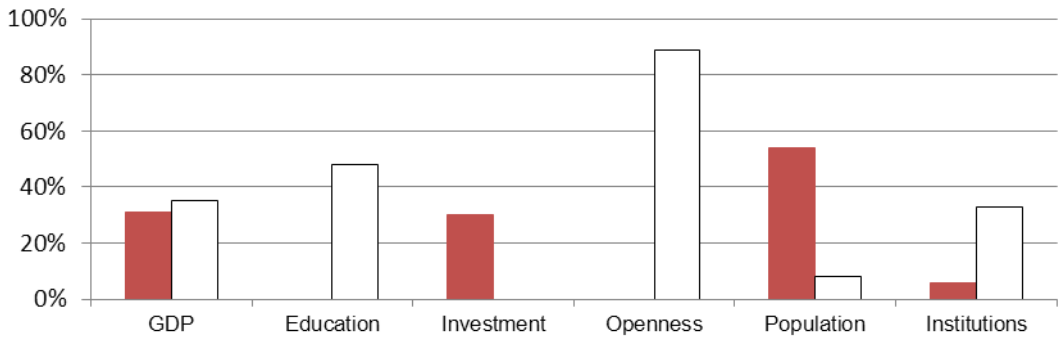
First, we find only full agreement in both bodies of literature for the case of investment where – independent of model type – the negative and significant t-values clearly outnumber the positive and significant t-values.

Second, for all other variables we find clear indications of disagreement in the aggregate and this is driven by the model type. For example, the evidence of resilience variable/model type 1 studies for openness and institutions is opposite to the evidence of disaster variable/model type 2 studies. (Remember that in model type 1 the collected t-values refer to the ability of the considered resilience factor to reduce disaster direct cost. The collected t-values for model type 2 reflect instead the effect of the inclusion of a resilience factor in the analysis of disaster indirect costs rather than quantifying its effects.)

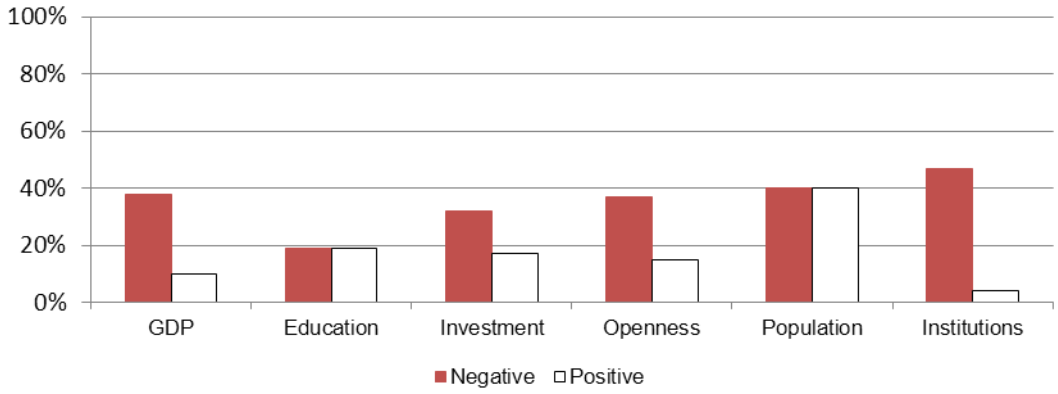
Third, no consensus can be derived on the role of resilience factors. Clearly theoretical and empirical choices in the construction of the model require more attention from the authors since these decisions seem to essentially influence the sign and significance of natural disaster impacts.

[6] Cross-referencing between Model type 1 and Model type 2 studies and vice versa occurs regularly in this literature.

FIGURE 3
The effects of resilience factors on disaster impacts by model
3a Model type 1 (periods in which disasters occurred)



3b Model type 2 (disaster and non-disaster periods)



Source: Lazzaroni and van Bergeijk 2013, Appendix Table A1

Figure 3 raises yet another issue, because the results may also be partially driven by econometric issues (sample size, data source and estimation technique), by temporal and spatial distributions of natural events (the latter determine disaster incidence) and by the type of disaster (earthquakes, floods, etc.) (*cf.* UNDP 2004: 3). Hence it is the combination of both natural and physical-socio-economic systems that ultimately determines the severity of the disaster-induced imbalance (Albala-Bertrand, 1993; Rasmussen, 2008). So the need arises of a multivariate analysis. This is where meta-analysis regression is highly useful. The combined analysis also may shed light on the role of considered resilience factors in determining disasters impacts in the short- to long-run.

4 Meta-analysis: preliminary results

In our analysis we will distinguish three categories of explanatory variables

- Variables that characterize the empirical design such as the number of observations or the period of research, the data source and the geographical dimension (number of countries and region).
- Estimation techniques (time series, panel, cross section, Ordinary Least Squares, Generalized Method of Moments and Fixed Effects).
- Resilience factors (macroeconomic production, population, education, investment, openness and institutions).

TABLE 1
Definition of variables and descriptive statistics

Variable	Description	N	Mean	St.D.
Empirical design				
N observations	Number of observations in the original regression	659	362	830
EM-DAT	1 if data on disasters were taken from EM-DAT, else 0	659	0.91	0.29
Climatic disaster	1 if climatic natural disasters were included, else 0	659	0.84	0.36
Geologic disaster	1 if geologic natural disasters were included, else 0	659	0.81	0.40
Other disaster	1 if non-natural disasters were included, else 0	659	0.37	0.48
N years	Period considered in the estimation	659	29	10
1960s	1 if dataset was including disasters in the '60s, else 0	659	0.19	0.39
1970s	1 if dataset was including disasters in the '70s, else 0	659	0.67	0.47
1980s	1 if dataset was including disasters in the '80s, else 0	659	0.93	0.25
1990s	1 if dataset was including disasters in the '90s, else 0	659	0.97	0.16
2000s	1 if dataset was including disasters in the '00s, else 0	659	0.82	0.38
N countries	Number of countries in the sample	652	75.35	41
Africa	1 if African countries were included, else 0	602	0.86	0.35
Asia	1 if Asian countries were included, else 0	602	0.93	0.26
Europe	1 if European countries were included, else 0	602	0.80	0.40
LAC	1 if Latin American–Caribbean countries were included, else 0	602	0.95	0.21
North America	1 if North American countries were included, else 0	602	0.87	0.21
Oceania	1 if countries in Oceania were included, else 0	602	0.79	0.41
OECD	1 if OECD countries were included, else 0	647	0.79	0.41
Non OECD	1 if non-OECD countries were included, else 0	647	0.93	0.25
Long-run	1 if the study consider impact in the long-run, else 0	659	0.34	0.48
DVAR	1 if the t value corresponds to a disaster indicator, else 0	659	0.56	0.50
TYPE2	1 if the study is of model type (2), else 0	659	0.47	0.50
Estimation technique				
Panel	1 if dataset was panel (0=cross-section) , else 0	659	0.83	0.37
OLS	1 if the estimation is conducted with OLS, else 0	659	0.45	0.50
GMM	1 if the estimation is conducted with GMM, else 0	659	0.12	0.32
FE	1 if the estimation uses fixed effects, else 0	659	0.23	0.42
Resilience factors				
Population	1 if an indicator of population is included, else 0	659	0.21	0.41
GDP	1 if an indicator of income is included, else 0	659	0.68	0.47
Education	1 if an indicator of education level is included, else 0	659	0.24	0.43
Investment	1 if an indicator of capital formation is included, else 0	659	0.22	0.41
Openness	1 if an indicator of openness is included, else 0	659	0.26	0.44
Institutions	1 if an indicator of institute. quality is included, else 0	659	0.13	0.34

Source: Lazzaroni & van Bergeijk, 2013, Table 7.

These variables in our study act as the control variables that enable us to distil the 'true' meta-effect from the primary studies. Table 1 lists these variables, provides a description as well as the number of observations (*t*-values that could be derived and/or calculated from the primary studies) as well as their means and standard deviations.

Our preliminary results (Table 2) show that the empirical design of the studies is highly relevant for the sign and level of significance of estimated disaster impact. In particular, when a disaster indicator (DVAR=1) is included in the model the probability to find a negative and significant coefficient increases by 0.64 while the use of model type 2 reduces the probability to find a significantly negative coefficient by 0.42 and at the same time increases the likelihood to find a positive and significant coefficient by 0.88.

Focusing on the methodology, we note that both the use of the EM-DAT dataset, the inclusion of more recent years and of more countries as well as accounting for regions, also influence the reported marginal impact of disaster outcome and of some resilience factors.[7] From this observation follows that attention should be paid to the assessment methodology and datasets used in analyses of macroeconomic policy decisions in disaster aftermaths or in building disaster resilience.

When interpreting the findings of the meta regression in Table 2, it is also important to note that the results to some extent may be biased due to existing gaps in the literature. To date only rather few studies are accounting for population and institutions (compare Figure 4). There is somewhat more evidence for education and openness. Finally, Figure 4 illustrates that presently most evidence is available for GDP and investment.

One of the major problems with doing meta-analyses in economics is that primary studies do not always provide the necessary parameters. In the case of natural disasters we had to exclude the studies of Padli and Habibullah (2009) and Jaramillo (2009) because these authors were not reporting the number of observations in the estimations presented in the primary studies. This is actually a quite general nuisance. Moons and Van Bergeijk (2013) analyzing the impact of economic diplomacy report that of the 1334 coefficients taken from 30 studies only 643 *t*-values were reported or could be calculated (48%) because essential information such as standard errors was missing in the primary studies. However, this is not a problem that is typical for economics – comparable problems also occur in fields where meta-analysis is well-established as a tool to synthesize knowledge (see for example Goodman et al. 2013).

[7] Note also that the total number of studies in Table 2 is 18 instead of 20 because due to missing list of countries included in the primary studies, two studies (Strömberg, 2007 and Tavares, 2004) were automatically excluded from the results.

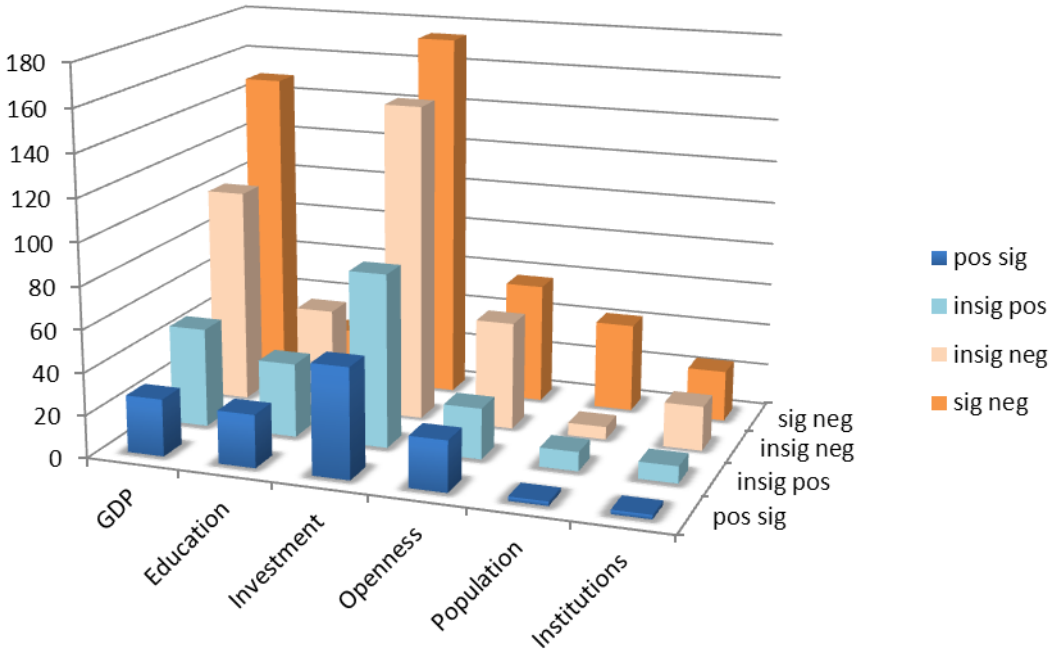
TABLE 2
Meta regression analysis. Multinomial logit, dependent variable: disaster impact effects

Outcome	Disaster Impact (DI)							
	(1)		(2)		(3)		(4)	
	Significant and negative		Negative but insignificant		Positive but insignificant		Significant and positive	
P(DI=outcome), (St.Dev.)	0.34	(0.31)	0.22	(0.22)	0.17	(0.18)	0.27	(0.32)
N observ.	0.00	(-0.05)	0.00	(1.5)	0.00 *	(-1.95)	0.00	(0.02)
1960s°	0.10	(1.02)	0.07	(0.74)	-0.19 *	(-1.7)	0.02	(0.23)
1970s°	0.00	(-0.04)	0.01	(0.12)	0.22 **	(2.35)	-0.23 ***	(-3.46)
1980s°	-0.46 **	(-2.59)	-0.35 **	(-2.13)	-0.43 **	(-2.76)	1.23 ***	(5.16)
1990s°	-0.56 ***	(-2.9)	-0.45 **	(-2.55)	-0.13	(-0.84)	1.15 ***	(4.9)
2000s°	-0.36 **	(-2.52)	-0.49 ***	(-3.6)	-0.30 **	(-2.29)	1.15 ***	(4.75)
N countries	0.00 ***	(2.88v	0.00	(-1.09)	0.00	(-0.45)	0.00	(-1.3)
Panel°	0.60 ***	(2.86)	0.41 *	(1.81)	0.68 ***	(3.14)	-1.69 ***	(-4.21)
EM-DAT°	-0.36 ***	(-3.33)	0.27 **	(2.27)	0.11	(1.05)	-0.02	(-0.29)
Climatic°	0.00	(0.02)	-0.12 **	(-1.95)	-0.10	(-1.46)	0.21 ***	(3.23)
Geologic°	-0.20 ***	(-3.4)	0.29 ***	(4.02)	0.01	(0.14)	-0.10 *	(-1.85)
Other°	0.08	(0.85)	-0.21 **	(-2.22)	0.03	(0.38)	0.10	(1.06)
Africa°	-0.14	(-0.84)	-0.42 **	(-2.67)	0.20 *	(1.63)	0.36 **	(2.84)
Asia°	-0.76 ***	(-2.79)	0.30	(0.81)	-0.76 ***	(-3.22)	1.22 ***	(3.28)
Europe°	-0.23	(-1.46)	0.24	(1.36)	-0.16	(-1.02)	0.15	(0.93)
LAC°	0.31	(1.24)	1.51 ***	(4.52)	0.08	(0.44)	-1.90 ***	(-5.68)
North America°	-0.06	(-0.37)	-0.42 *	(-1.8)	0.03	(0.24)	0.45 **	(2.12)
Oceania°	0.20	(1.59)	-0.26 *	(-1.79)	0.30 **	(2.23)	-0.24 *	(-1.92)
Long-run°	0.02	(0.21)	-0.16	(-1.51)	0.21 ***	(3.07)	-0.06	(-0.63)
DVAR°	0.64	(0.05)	0.53	(0.04)	0.37	(0.02)	-1.54	(-0.04)
TYPE2°	-0.42	(-0.03)	-0.23	(-0.02)	-0.24	(-0.01)	0.88	(0.02)
OLS°	-0.28 ***	(-2.99)	-0.03	(-0.38)	0.07	(0.76)	0.25 ***	(3.03)
GMM°	-0.24 *	(-1.96)	0.07	(0.59)	0.07	(0.54)	0.11	(0.62)
FE°	0.11 **	(2.11)	0.05	(0.87)	0.04	(0.69)	-0.20 ***	(-3.3)
Population°	0.36 ***	(5.48)	0.06	(1.14)	-0.18 **	(-2.88)	-0.24 ***	(-4.77)
GDP°	0.08	(1.32)	-0.15 **	(-2.56)	-0.04	(-0.84)	0.10 ***	(2.78)
Education°	-0.11	(-1.29)	0.07	(1.1	-0.01	(-0.24)	0.05	(1.1)
Investment°	0.18 ***	(2.76)	0.08	(1.09	-0.11	(-1.62)	-0.16 *	(-1.94)
Openness°	-0.02	(-0.24)	0.00	(-0.02	-0.11 *	(-1.67)	0.13 **	(2.38)
Institutions°	0.04	(0.07)	0.08	(1.27)	0.01	(0.09)	-0.12	(-1.77)
Pseudo R^2								0.40
N studies								18
N observations								594

Source: Author's elaborations.

Note: ° change from zero to one. Z-values in parenthesis. Standard errors clustered by studies. *, **, *** stands for 10, 5 and 1% level of significance.

FIGURE 4
Number of coefficients for different resilience variables



Source: Lazzaroni and van Bergeijk, 2013, Appendix Table A2.

Clearly the studies influence the policy domain as illustrated in Table 3 where we trace the impact of scientific studies on the macroeconomic impact of disasters in policy documents. By implication contradictions in terms of impact of mitigating factors will have an impact on policy advice and implementation. Whereas the aggregate evidence for type 1 models suggests a strategy aimed at education, openness and institutional reforms, type 2 models suggest that these factors do not help to mitigate the impact of disasters.

Evidently then the course of government policies is influenced by the literatures that are being studied. Combining the two strands of the literature does not solve this issue although it creates clear awareness of the preliminary status of empirical advice and its robustness. Moreover, it highlights where the literature needs to be complemented to fill some gaps in the analysis of a given topic.

As Figure 4 shows the number of *t*-values per selected factors of resilience (and their relationship with the dependent variable), the role of institutions and population in the macro-econometric studies on disasters impact has not been extensively explored. The meta-analysis thus suggests that these relationships should be more explored in order to better understand if and how institutions and population influence the impact of natural disasters on the economies considered.

TABLE 3
Studies included in the meta analysis and major policy documents

Study used for the meta-analysis by model type	Major policy documents in which it is cited
Rasmussen (2004)	Hochrainer (2009)
	Kisanga et al. (2006)
	Jayraman (2006)
	Cashin et al. (2006)
	IPCC (2012)
Anbarci et al. (2005)	Kenny (2009)
	OIC (2012)
Kahn (2005)	Bussel and Colligan (2013)
Escaleras et al. (2007)	
Stromberg (2007)	O'Brien et al. (2008)
Toya ad Skidmore (2007)	Von Peter et al. (2012)
	Liborio (2011)
	IPCC (2012)
	O'Brien et al. (2008)
Kellenberg and Mobarak (2008)	IPCC (2012)
Raschky (2008)	IPCC (2012)
Padli and Habibullah (2009)	
Padli et al. (2010)	
Skidmore and Toya (2013)	
Skidmore and Toya (2002)	IPCC (2012)
	UNISDR (2013)
Haeger et al. (2008)	IPCC (2012)
Tavares (2004)	
Noy and Nualsri (2007)	IPCC (2012)
Noy (2009)	IPCC (2012)
	UNISDR (2013)
Jaramillo (2009)	IPCC (2012)
Kim (2010)	
Vu and Hammes (2010)	
Bergholt (2010)	
Strobl (2011)	IPCC(2012)
Loayza et al. (2012)	World Bank (2014)
	IPCC (2012)

Source: Authors' elaborations.

5 Case study: IPCC report versus Meta-analysis

In order to 'frame the challenge of dealing with extreme weather and climate events as an issue in decision-making under uncertainty, analyzing response in the context of risk management' (IPCC, 2012: *viii-ix*) Working Group I and II

of the International Panel on Climate Change (IPCC)[8] jointly produced a special report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (henceforth 'the IPCC Report'). The objective of the IPCC Report is to provide a comprehensive assessment of the literature on climate change (the usual domain of IPCC) with a focus on disaster recovery, risk management and mitigation up to May 2011. The stated scope is explicitly limited to 'assess science in a way that is relevant to policy but not policy prescriptive' (IPCC, 2012: *ix*). We note, however, that due to the controversy and methodological heterogeneity of the macroeconomic literature on natural disasters, any decision regarding inclusion and presentation of results from a selection of studies will shape policy decisions as it influences and limits the policy maker's information set.

5.1 Structure of the IPCC report vs structure of the meta-analysis

The IPCC Report starts by acknowledging that the effects of extreme weather and climate events originate from a combination of physical characteristics of the event and the social aspects of disasters that ultimately frame risk, exposure and vulnerability. In chapter 2 the dimensions of vulnerability from disasters are categorized into environmental, social, economic and cross-cutting themes (food security and political ecology are some examples), covering some of the variables involved in macro-econometric studies that we considered in the meta-analysis. However, as illustrated in Table 4, the variables and concepts that play an important role in the macro-econometric studies appear with low frequency in the IPCC Report.

Environmental aspects include the physical (location-specific context combinations of human interaction with the material world) and geographical (world and regional) occurrence of the natural hazard. The social dimensions covered by the IPCC Report incorporate demographic aspects (population and its structure), migration and displacement (population dynamics), education (educational facilities and system and availability of knowledge about disaster risk reduction and climate change adaptation) and institutional and governance aspects (formal and informal structures that manage natural resources and shape and implement policies for disaster risk management, climate change adaptation and development). The economic dimensions include the country GDP level (as

[8] The IPCC was created in 1988 with the general mandate "[…] to assess in a comprehensive, objective, and transparent manner all the relevant scientific, technical, and socioeconomic information to contribute in understanding the scientific basis of risk of human-induced climate change, the potential impacts, and the adaptation and mitigation options" (IPCC, 2012: vii). It is coordinated by Working Group I and II, respectively dealing with physical science basis of climate change and climate change impacts, adaptation and vulnerability.

indicator of wealth and the potential to spend more for post-disaster recovery), the possibility to access international public/private financial and technical assistance and the availability of market-based insurance. Note that some aspects of these three broad dimensions could be considered in the IPCC Report, but not in our meta-analysis due to their lower level of aggregation[9]. Chapter 3 deals with pattern and impact of climate extremes in the natural physical environment while disaster costs – the core research question analyzed in the meta-analysis – are discussed extensively in Chapter 4, and in less in depth in Chapters 5 and 6 focusing on theories of adaptation at the local and national level and in Chapter 8 exploring the interactions among sustainable development and the impact of natural disasters.[10]

TABLE 4
Entries of selected keywords found in the IPCC Report

Keyword	Number of pages with citation	Number of citations in overall Report
General topic		
Climate change	559	1758
Risk	458	3285
Disaster	427	2727
Adaptation	375	1483
Vulnerability	358	1070
Extreme event	341	2033
Resilience factors		
Institutions	200	302
Population	170	322
Governance	141	161
Investment	86	105
Education	85	113
School	49	55
GDP	33	68
Openness	2	2

Source: Authors' elaborations from IPCC (2012).

[9] The IPCC Report also mentions patterns of urban/rural settlement in the environmental dimension and vulnerability of particular social groups, health and wellbeing and cultural aspects in the social dimension (IPCC, 2012: 80). Note that these aspects are considered in some macro-econometric studies using country fixed effects in the estimation technique (Heger et al., 2008; Kellenberg & Mobarak, 2008).

[10] Adaptation at the international level is dealt with in Chapter 7 without explicit references to the macro-econometric literature on disaster impact while Chapter 9 presents case studies.

5.2 Disaster costs

The IPCC Report defines the "*impact of climate extremes and disasters* on economies, societies and ecosystems […] as the *damage costs* and *losses* of economic assets or stocks, as well as consequential indirect effects on economic flows, such as on GDP or consumption" (IPCC, 2012: 264, italic in the original). So as in our meta-analysis, a categorization into direct, indirect (and secondary), and intangible costs is made, explicitly pointing out that the categories are 'rarely fully exclusive, and items or activities can have elements in all categories'. The IPCC Report provides a review of the macroeconomic literature dealing with natural disasters, considering the two basic research questions at the base of the meta-analysis.

Sign of impact on economic development

The first basic research question relates to the sign of the impact on economic development. Table 5 lists the studies cited in the IPCC Report finding a negative or positive impact on growth in the short- and long-tem. Combining Table 5 with the correspondent studies in the meta-analysis allows us to make six observations.

Firstly, there is high prevalence of non-macroeconometric studies[11] in the IPCC information set.[12]

Secondly, in line with the discussion of the meta-dataset descriptive statistics, IPCC acknowledges the disagreement in the literature and assigns 'medium confidence'[13] to the prevalence of a negative impact in the short run. The meta analysis by pooling results across studies clarifies that the evidence available in the considered macroeconometric studies can justify more confidence with respect to the impact of the disaster.

Thirdly, disagreement is seen by IPCC as the result of some limitations in the analyses such as lack of counterfactual or the failure to account for the role of informal sector, insurance, aid and disaster type. In the meta-analysis disagreement is by and large related to dataset and methodological choices by the authors of the primary studies.

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[11] Some macro-econometric studies are included in the non-macroeconometric category due to their unsuitability for the meta-analysis: Hochrainer (2009) uses as dependent variable the difference between projected and observed GDP in 5 years *post* event instead of GDP level/growth, Raddatz (2009) relies on a VAR analysis and Jaramillo (2009) didn't report the number of observations in the regression results.

[12] The study by Kellenberg and Mobarak (2008) does not report an econometric analysis of the disaster-growth relationship but discusses it, hence it is nevertheless reported in the short-term, negative category column of the meta-analysis studies.

[13] In the Report the degree of certainty in key findings is based on authors' evaluation of scientific knowledge using the qualitative concept of *confidence*. Confidence can be low, medium and high depending on the authors' evaluation of the level (low, medium, high) of agreement and type, amount and consistency (limited, medium, robust) of the evidence included in the literature reviewed.

TABLE 5
Nature of the impact of natural disasters on economic development
(growth-Model type 2)

	Studies in the IPCC Report		Studies in the meta-analysis before May 2011)	
Time[§]	**Negative**	**Positive**	**Negative**	**Positive**
Short-term (<=3 years)	Benson and Clay (1998°; 2000*; 2003; 2004)* Kellenberg & Mobarak (2008) Cuny (1983)* Otero & Marti (1995)* Charveriat (2000)* Crowards (2000)* ECLAC (2003)* Mechler (2004)* Raddatz (2009)* Noy (2009) Okuyama & Sahin (2009)° Cavallo & Noy (2010)*	Albala-Bertrand (1993)* Skidmore & Toya (2002) Caselli & Malthotra (2004)* Hallegatte & Ghil (2007)*	[Kellenberg & Mobarak (2008)] Heger et al. (2008) Bergholt (2010) Noy (2009) Vu & Hammes (2010)	
			Mixed evidence Strobl (2011)	
Long-tem (>3years)	Noy & Noualsri (2007) Hochrainer (2009)* Jaramillo (2009)*		Noy & Noualsri (2007)	Skidmore & Toya (2002) Tavares (2004) Kim (2010)
	Mixed evidence World Bank and UN (2010)* for very severe disasters		**Mixed evidence** Loayza et al. (2012) Jaramillo (2009)*	

Source: Authors' elaborations from IPCC (2012: 264-269, 344-345, 443-445), sections 4.5, 6.1 and 8.2.1.

Fourthly, the study by Skidmore and Toya (2002) is cited by IPCC as short-term study supporting a positive effect of natural disasters but the period considered in the article is long (the dependent variable is the 30 years average per capita GDP growth rate).

Fifthly, some readily available macro-econometric studies were not included in the literature cited in the ICPP Report both in the case of short-term negative (Heger et al., 2008; Bergholt, 2010; Vu & Hammes, 2010) and medium to long-term positive (Kim, 2010; Tavares, 2004) or mixed (Loayza et al., 2012) findings about the impacts of natural disasters.

Finally, two suitable studies were not included in the meta-analysis (Benson & Clay, 1998; Okuyama & Sahin, 2009).[14]

Nexus between development an disaster vulnerability

The second basic research question emerges where the IPCC Report discusses the nexus between development and disaster vulnerability, highlighting some key relationships.

Table 6 lists the studies in the IPCC Report that support a certain relationship and the studies in the meta-analysis showing similar findings. Again, immediately we can note the prevalence of non-macroeconometric studies in the IPCC

[14] Benson & Clay (1998) does not report the number of observations, so it would have been excluded in any case, except if the authors had provided the missing information.

information set and the neglect of some macro-econometric studies in both the IPCC Report and in the meta-analysis. For example, the IPCC does not cite Padli et al. (2010) to support the statement that 'wealthier countries experience higher total economic and insured losses'.

Only one reference in the Report is given to highlight the importance of institutional capacities (Moreno & Cardona, 2011) while this relationship is supported by four studies in the meta-analysis (Anbarci et al., 2005; Kahn, 2005; Raschky, 2008; Strömberg, 2007).

TABLE 6
Nexus between development and disaster vulnerability

Relationship analyzed	Studies in the Report	Additional information	Studies in the meta-analysis (before May 2011)
Poorer developing countries and smaller economies are more likely to suffer (especially for very extreme events)	World Bank (2000)* IPCC (2001)* UNDP (2004)* O'Brien et al. (2006)* Thomalla et al. (2006)* Hallegatte et al (2007)* Parry et al. (2007)* World Bank (2007)* Heger et al. (2008)* Nicholls (2008)* Hallegatte & Dumas (2009)* Ibàrraran et al. (2009)* Loayza et al. (2009) Raddatz (2009)* Lal (2010)* Rodriguez-Oreggia et al. (2010) Wildavski (1988)* Albala Bertrand (1993)* Burton et al. (1993)* Tol & Leek (1999)* Mechler (2004)* Rasmussen (2004) Brooks et al. (2005)* Kahn (2005) Toya & Skidmore (2007) Raschky (2008) Noy (2009) Cavallo & Noy (2009)*	More vulnerable because -less resilient due to dependence on natural capital and climate-sensitive activities -poorly prepared -maladaptation due to lack of finances, information and techniques, weak governance -little climate-proof investments -adaptation deficit and insurance deficit due to low development -large informal sectors -multiple/consecutive disasters Wealthier country are better equipped (ex-ante & ex-post) thanks to -higher income -more governance capacity -higher expertise -ammassed climate-proof investments -improved insurance systems	Rasmussen (2004) Kahn (2005) Toya & Skidmore (2007) Raschky (2008) Loayza et al. (2009) Noy (2009) Anbarci et al.(2005) Heger et al. (2008)
Adverse effects in developing countries (various measures)	Otero & Marti (1995)* Charveriat (2000)* Crowards (2000)* Murlidharan & Shah (2001)° ECLAC (2003)* Del Ninno et al. (2003)+ Owens et al. (2003)+ Skoufias (2003)+ Benson & Clay (2004)+ Mechler (2004)* Hochrainer (2009)*		Noy (2009) Vu & Hammes (2010)

	Hallegatte et al. (2007)+ Raddatz (2007)+ Noy (2009) Cardona et al. (2010)+ IFRC (2010)+ Lal (2010)*		
Wealthier countries experience higher total economic and insured losses	UNDP (2004)* DFID (2005)* Birch & Wachter (2006)* O'Brien et al. (2006)* Cutter & Finch (2008)* Kellenberg & Mobarak (2008) Cummins & Mahul (2009)* UNISDR (2009)* Swiss Re (2010)* Cavallo & Noy (2010)* CRED (2010)* Pelham et al. (2011)*	-social vulnerability -inadequate disaster protection	Kellenberg & Mobarak (2008) Padli et al. (2010)
Higher vulnerability for small island states also for damages	McKenzie et al. (2006)* World Bank & UN (2010)*		Rasmussen (2004)
Non-linear relationship income-disaster costs	Kellenberg & Mobarak (2008) Patt et al. (2010)°		Kellenberg & Mobarak (2008)
Fatalities decrease with rising income	Kahn (2005) Toya & Skidmore (2007) World Bank & UN (2010)* BUT Bouwer et al. (2007)* Nicholls et al. (2008)*	Relationship seem reverted if accounting for projected increased exposure due to urbanization and rapid economic growth	Kahn (2005) Toya & Skidmore (2007)
Capacities and political priorities determine disaster management and impact	Moreno & Cardona (2011)°		Kahn (2005) Raschky (2008) Anbarci et al. (2005) Strömberg (2007)
Needed integration between DDR, climate change adaptation and sustainable development	O'Brien et al. (2006)*+ Schipper & Pelling (2006)*+		

Source: Authors' elaborations from IPCC (2012: 264-269, 344-345, 443-445), Sections 4.5, 6.1 and 8.2.1.

Notes: * stands for reports, books, non-econometric studies or econometric studies that could not be included in the analysis due to missing information. ° identifies a study that is in the IPCC information set but not in the meta-analysis. + stands for studies that were cited to back a particular policy option.

Section 5.5.2 of the IPCC Report cites studies focused on disasters impact at the local level (Table 7). Non-macroeconometric analyses prevail but here this is motivated by the nature of the research question. The impact of natural disasters at the local level can be better analyzed with input output and CGE models, however by construction the results of these analyses cannot be included in a meta-analysis.

TABLE 7
Studies estimating the cost of managing disasters at the local level

Studies in the IPCC Report	Studies in the meta-analysis (before May 2011)
West & Lenze (1994)*	Strobl (2011)[#]
Rose et al. (1997)*	
Okuyama (2004)*	
Haimes et al. (2005)*	
Rose & Liao (2005)*	
Smith & McCarty (2006)*	
Tsuchiya et al. (2007)*	
Hallegatte (2008)*	
Strobl (2008)[#]	
Noy & Vu (2010)°	
Rodriguez-Oreggia et al. (2010)*	

Source: Authors' elaborations from IPCC (2012: 317), Section 5.5.2.1.

Notes: * stands for reports, books, non-econometric studies or econometric studies that could not be included in the analysis due to missing information.
[#] the study in the IPCC Report is the working paper version while in the meta-analysis we reported the published in a journal.
° identifies a study that is in the IPCC information set but not in the meta-analysis.

5.3 Conclusions on the IPCC case

From the comparison between the IPCC Report and the meta-analysis discussion of disaster cost we can draw three general conclusions.

First, a number of studies were not included in our meta-analysis but appear in the IPCC Report information set (Benson & Clay, 1998; Murlidharan & Shah, 2001; Moreno & Cardona, 2010; Noy & Vu, 2010; Okuyama & Sahin, 2009; Patt et al., 2010) and viceversa depending on the relationship discussed. As far as the meta-analysis is concerned, possible explanations of this lack of comprehensiveness are a failure to meet keywords combinations in the phase of literature research or the absence of keywords in the study. For example, the study by Moreno & Cardona (2010) is a background paper for the 2011 *Global Assessment Report on Disaster Risk Reduction* written in Spanish and without a keywords list.[15] Missing studies will be included in a future update of the meta-dataset.

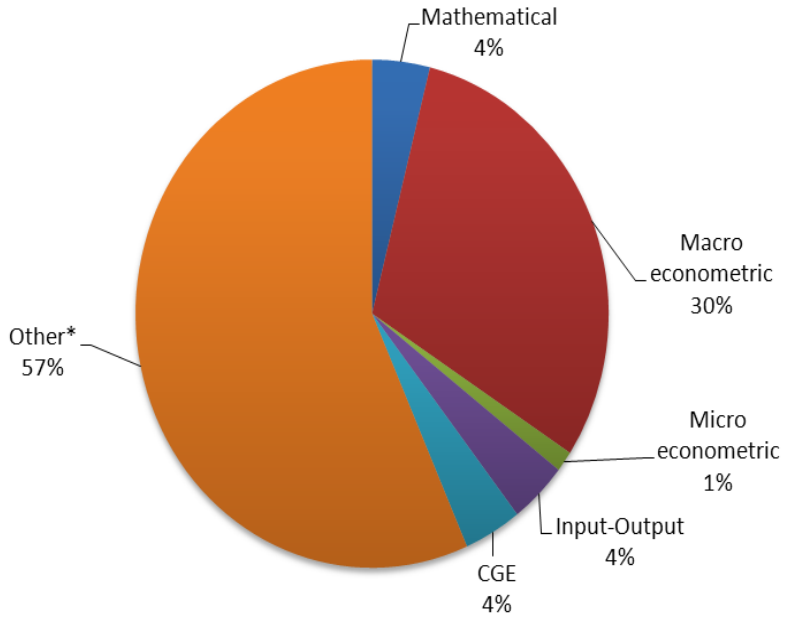
Second, as showed by Figure 5, the IPCC Report relies more on non-macroeconometric studies for the discussion of disaster impacts, adding value in terms of strength of the arguments put forward.

Finally, although the IPCC Report as stated before explicitly wants to follow a non-normative approach (IPCC, 2012: ix), there is a clear focus on the differences of impact between developing and developed countries, suggesting that disasters can contribute to harm development (growth) especially in the short-term. We can say that the decisions about the literature presented are towards showing the need, especially for developing countries to implement policies that combine sustainable

[15] Other potential drawbacks of our technique to search the literature should be noted. For example using browsers such as Google Scholar may show path dependence (different computers may result in different lists of studies). Moreover, some World Bank policy working paper are hard to find with a general search. The reasons are, for the time being, unknown.

development with climate change adaptation and disaster risk reduction. However, the macro-econometric literature is coherently not advocated to push the adoption of specific measures such as increasing educational levels or investments. A clear example is the fact that the analysis of the relationship between disasters impact and education is neglected (the analysis of the relationship between income and disaster impact is preferred). Another example is the reference to the role of institutions: the IPCC Report cites the study by Moreno and Cardona (2010) to suggest that enhancing capacity and political priority towards disasters risk management is crucial to mitigate their impacts but the Report does not refer to macro-econometric studies explicitly accounting for institutional/governance effectiveness measures (Anbarci et al., 2005; Kahn, 2005; Strömberg, 2007; Raschky, 2008).

FIGURE 5
Studies (76) on disaster impacts in the IPCC report by type of analysis



Source: Authors' elaborations from IPCC (2012: 264-269, 317, 344-345, 443-445).
Note: *the category includes reports, books and studies with descriptive analyses.

6 Conclusions, policy implications and areas for further research

Recent years have witnessed a strong increase in the number of available studies on the macroeconometric impact of natural disasters. These studies, as in any emerging field of science, are heterogeneous both in terms of findings and methodological characteristics. In this article we applied a meta-analysis providing descriptive bibliometric statistics and an econometric synthesis of the literature. Our 22 preliminary studies were identified with an internet search and mainly consist of articles and academic English language working papers. We confronted this methodology with the authoritative narrative literature review of the IPCC Report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. Table 8 provides an overview of strengths and weaknesses.

TABLE 8
Strengths and weaknesses of traditional literature review and meta-analysis

	Traditional literature review (IPCC 2012)	Meta analysis (Lazzaroni and Van Bergeijk 2013)
Qualitative analysis and case studies	yes	no
Quantitative analysis	yes	Yes, but not CGE, VAR and Input-Output
Identification of methodological differences	yes	yes
Identification of *impact* of methodological differences	no	yes
Possibility to include 'incomplete studies'	yes	no
Coverage of literature relevant for method	Incomplete (selective)	Incomplete (search strategy)
Transparent non-subjective synthesis	no	yes

Source: Authors' elaborations.

The traditional narrative literature synthesis clearly has strong points mainly related to its ability to also include purely qualitative analysis (including mathematical models), case studies and studies that by their very nature do not report significance levels (input-output models, Vector Auto Regressive models and Computable General Equilibrium models). Incomplete or inaccurate studies (for example those that fail to report standard errors, t-values or the number of observations) can still be considered in the traditional review of literature.

Our meta-analysis does not take these studies and analyses into account although these economic tools certainly generate valuable scientific knowledge. On the other hand the method to synthesize the knowledge is completely transparent for meta-analyses and this is a benefit in a highly political area such as the developmental perspective on the impact of natural disasters. Importantly meta-analysis helps to uncover the relationship between findings in primary studies and their methodological characteristic.

One finding that is of particular relevance in comparing the relative merits of a meta-analysis and a traditional review of literature is the incomplete coverage of studies that can be observed when we compare the two approaches. This is partly due to the fact that our meta-analysis is based on an internet search where academic articles and working papers have a higher probability to be found. The incomplete coverage also may reflect the inability to cope with certain methods and methodologies and the data requirements of meta-analyses.

Finally, it may be a consequence of subjective decisions to include or exclude studies. Our take on this is that the two methods force two different perspectives on researchers and that each perspective helps to uncover other (aspects of) literatures. If that is the case then research synthesis would benefit from combining the two approaches. So we arrive at two intertwined conclusions. A meta-analysis without a traditional review of the literature is incomplete. A traditional review of the empirical literature is equally incomplete without a meta-analysis.

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Appendix A: References for policy reports

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