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Analysis

Natural disasters' impact, factors of resilience and development: A meta-analysis of the macroeconomic literature

Sara Lazzaroni [a,*], Peter A.G. van Bergeijk [b,1]

[a] Department of Economics, University of Bologna, Piazza Scaravilli 2, 40126, Bologna, Italy
[b] International Institute of Social Studies of the Erasmus University, Kortenaerkade 12, 2518 AX, The Hague, Netherlands

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ABSTRACT

We systematize 64 primary studies published in 2000–2013 on the macroeconomic impact of natural disasters by providing OLS and generalized ordered probit meta-analyses for 1858 and 1991 regressions, respectively. We investigate how the reported results in the primary studies are influenced by the empirical design, the estimation technique, and/or publication bias. We analyze primary studies on disaster direct costs and indirect costs separately. According to our meta-analysis, disasters on average have a negative impact in terms of direct costs and an insignificant impact in terms of indirect costs.

MST and FAT–PET–PEESE estimates motivate the meta-analyses showing the need for a multivariate approach to consider strong systematic research heterogeneity. Time-based characteristics of the data and publication bias strongly impact on the results of the primary studies, thus implying the need for authors to carefully consider the selection of time period and for research institutions to understand the sources of selection bias in disseminated results. We argue that further research is necessary on the heterogeneity of results of indirect cost studies and suggest that future studies on the macroeconomic impact of disasters should explore more often the mitigation role of education, investment and openness by including these as explanatory variables.

1. Introduction

Small to large scale natural disasters have always affected societies around the world. Still the economics of natural disasters is a fairly recent branch of the economic research (Okuyama, 2007; Pelling et al., 2002). Before the 2000s this topic was almost exclusively in the domains of other disciplines of social sciences and the technical sciences (Cavallo and Noy, 2010). However, due to both the higher frequency and intensity of natural disasters and their relation to global warming the empirical literature on the economic impact of natural disasters has grown substantially during the last decade (Raschky, 2008).

The IPCC (2012) defines natural disasters as "[s]evere alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery".[2]

Hence, the economics of natural disasters is highly intertwined with the study of the determinants of poverty and development (including the role of risk, shocks and vulnerability) where it investigates the effects of natural hazard on individuals, households and the overall economy. The quest on whether disasters are a problem *of* or *for* development started with the seminal works of Albala-Bertrand (1993a, 1993b) who developed a model and provided empirical estimates that indicate that the long run growth impact of a disaster-induced capital loss is small, so that a moderate increase in expenditures may be sufficient to prevent the growth rate of output from falling. From this provocative starting point, the literature has developed at three levels. The first level is micro-econometric and focuses on the effects of environmental shocks on households and individuals and their ability to prepare and cope with disasters (see for example Dercon, 2004; Kazianga and Udry, 2006 on rainfall variations/droughts and consumption or Dercon and Krishnan, 2000; Frankenberg et al., 2011; Maccini and Yang, 2008 on rainfall extremes/tsunami and health outcomes). The second level consists of case studies regarding specific disastrous events and the connected sectoral losses (Benson and Clay, 2004; Vos et al., 1999). The micro-econometric and case-study analyses substantiated the relevance of social, economic and institutional country-specific characteristics and provide the stepping stones for the third level (developed since the early 2000s): the macroeconomic impact of natural disasters (Noy, 2009). This literature is macroeconometric in

* Corresponding author. Tel.: +39 051 20 98131.
E-mail addresses: sara.lazzaroni@unibo.it (S. Lazzaroni), bergeijk@iss.nl (P.A.G. van Bergeijk).
[1] Tel.: +31 70 4260517.

[2] Other definitions put less emphasis on the linkages between intrinsically exogenous natural hazards and the socio-economic, demographic and institutional characteristics of the areas in which hazards occur (see EM-DAT, 2011; Hallegatte and Przyluski, 2010).

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nature and studies the economics of disasters from multi-country and/or multi-event perspectives. Its focal point is the sign (positive versus negative) and significance of the macroeconomic impact of natural disasters.[3]

In this article we focus on the macroeconomic analysis because this part of the literature is more homogeneous in terms of disaster outcome and models considered.[4] The macro econometric analyses focus on the effects of series of natural disasters and investigate their 'mean' costs (Hallegatte and Przyluski, 2010) and can be classified in

- *Direct costs* (represented by damages at the moment of the event: market losses such as damages to assets, goods and services for which a price is observable, and non-market losses like losses of lives or number of people affected by the disaster);
- *Indirect and secondary costs* (losses induced by disasters in terms of flows of goods, services and business revenues that will not be generated due to destruction or business interruptions and effects on the performance of the overall economy Hallegatte and Przyluski, 2010; Zapata-Marti, 1997: 10–11).

The analyses of direct and indirect costs are complementary in understanding the role of disasters during the process of development.[5] The literature on indirect impacts of disasters frequently refers to the literature on direct costs when motivating the empirical design of the studies.[6] However, given the fundamental differences between the two cost categories (van Bergeijk and Lazzaroni, 2013) we will deal with them separately.

The first objective of this paper is to understand if disasters *do* have an impact (significant or not) at the macroeconomic level and the direction of this impact (positive/negative). To do this we conduct two meta-analyses of the available 'primary' macroeconometric studies: a meta-analysis on disaster direct cost studies and a meta-analysis on disaster indirect cost studies. Meta-analysis is a relatively new research technique in economics, but is well accepted in medicine and psychology as a statistical tool to synthesize knowledge, increase power and precision of results, explain heterogeneity and correct findings for potential biases (Higgins and Green, 2011). In economic and policy-analyses it also helps to 'test economic theories; model the research process and give direction to future empirical investigation' (Stanley and Docouliagos, 2012). Recent examples in development economics include: Havránek and Iršová (2010), Doucouliagos and Paldam (2011), and Mebratie and van Bergeijk (2013).

We will analyze t-values and/or reported coefficients' sign and level of significance. First, disaster direct costs are measured both in market and non-market terms and we thus need a dimensionless parameter in order to make useful comparisons.[7] Note that the focus on t-values also in the meta-analysis on indirect cost studies allows further comparability and discussion of drivers of the results between the two substrands of the macroeconomic literature on natural disasters. Second, the functional forms used in the macroeconometric studies (log-log, log-linear, linear-log) often differ. This issue could be solved by applying simple formulas and using sample means (Gujarati and Porter, 2009). This is, however, not always possible because primary studies generally report only descriptive statistics for the full sample considered, while within the same study authors often present estimations on a variety of subsamples (for instance, a subsample for developing countries or climatic disasters) for which specific average characteristics are not provided (an exception is Cuñado and Ferreira, 2014). Using only regression results based on full samples would imply the loss of additional information on the effect of different sample characteristics (size, decades and countries included). We want to avoid this loss because the second objective of our meta-analysis is to understand how sample design and other methodological choices (disaster costs considered and model specification, estimation techniques) influence the results in the primary studies. In the words of Disdier and Head (2008: 43): "different estimates often differ in terms of sample period, method, etc., and therefore within-study variation […] can be used to assess the importance of such variables". In the meta-analysis we also account for study dependence effects through study-clusters. Third, to the extent that we model t-values according to levels of significance, we can include studies that do not report t-values and/or standard errors but do report coefficients and levels of significance. In the case of natural disaster this increases our sample size by 6.4% (7%) for direct (indirect) cost studies.[8] OLS results are also reported for comparison of the results.

We have identified 64 'primary' macroeconomic studies up till and including December 2013 that empirically try to assess the direct and indirect effects of natural disasters for a total of 1999 reported t-values (significance levels). Two working papers appeared as articles in 2014 (Cuñado and Ferreira, 2014; Neumayer et al., 2014), and here we use the 2014 articles. In our sample 31 studies investigate direct costs, 28 analyze indirect costs and 5 studies (Anttila-Hughes and Hsiang, 2013; Deryugina, 2013; Felbermayr and Gröschl, 2013a; Jackson, 2013; Zylberberg, 2012) consider both cost categories. The median coefficient of the primary direct cost studies is positive in 3 cases and negative in 33 studies.[9] The median coefficient in indirect cost studies is positive in 7 studies[10] and negative in 23 studies. Note that for three studies (Cuñado and Ferreira, 2014; Noy and Vu, 2010; Vu and Hammes, 2010) we do not report t-value aggregate statistics because they report only p-values or symbolic representations of the level of significance. The average t-value for direct cost studies is −5.93 and its standard deviation is 8.16, while the average t-value for indirect cost studies is

[3] The debate is very lively, with authors replicating studies to update results as disaster data become available (Skidmore and Toya, 2002; Kim, 2010), discussing the effects of different estimation techniques on the same dataset (Toya and Skidmore, 2007, 2013; Reed and Mercer, 2013) or building new disaster datasets to improve disaster reporting or include considerations on risk transfer (Czajkowski et al., 2011; von Peter et al., 2012).

[4] For example the microeconomic literature is very heterogeneous both in terms of the study-specific research questions and the coping strategy investigated, reflecting manifold contexts and mitigation actions at the household/individual level. Karim and Noy (2014) meta-analyze the relationship between poverty and natural disasters in microeconomic papers. They identify 62 studies but are able to retain only 38 studies (due to missing information or focus on coping strategies rather than disaster impact) for a total of 161 parameter estimates. Karim and Noy show that natural disasters negatively affect household income and (to a lesser extent) non-food consumption (housing, health, education). We refer to future research for the attempt to synthesize together the micro and macro econometric literatures with the use of a meta-analysis.

[5] Pelling et al. (2002: 285) point out that "[…] there are many linkages between [direct, indirect and secondary] losses. Direct losses are incurred during the damage stages of a disaster but may lead to indirect losses resulting in secondary effects that continue to be felt throughout the recovery stage and may shape the preconditions of subsequent vulnerability. Reduced output and employment opportunities from direct and indirect damage in impacted activities or economic sectors create knock-on indirect and secondary costs through reduction in consumption and investment, reduced productive capacity and increased social costs (resettlement, health impacts)."

[6] For example, Noy (2009) refers to Rasmussen (2004) and Kahn (2005) to support the inclusion of political economy and income level variables.

[7] This is a common nuisance encountered by other meta-analyses as well; see Waldorf and Byun (2005) and Moons and Van Bergeijk (2012).

[8] Excluding these observations reduces the share of significantly negative parameters from 73.5% to 72.5% for direct cost studies and increases the share of significantly negative parameters from 36.4% to 38.6% for indirect cost studies.

[9] For ease of discussion we report t-values always in a way that 'negative' impact means that the costs of the disaster are larger. In growth studies a negative t-value of the natural disaster variable indicates a growth slowdown. However, if the original study investigates the direct costs of a disaster (disaster damages, affected or killed) then a negative t-value in the original study indicates smaller impact. Hence, to allow comparisons between the studies we changed the sign of the parameters for the studies on disaster direct costs. Figures are based on data from Appendix Tables a.1 and a.2.

[10] Positive effects of natural disasters can be the outcome of effective disaster preparedness and mitigation (IPCC, 2012; Rasmussen, 2004; Kellenberg and Mobarak, 2008; Raschky, 2008), Schumpeterian "creative destruction" (Skidmore and Toya, 2002; Kim, 2010; Loayza et al., 2012), aid and foreign assistance (Heger et al., 2008; Noy, 2009), insurance and reinsurance (Rasmussen, 2004; Von Peter et al., 2012) or underestimation of disaster effects as recorded in disaster databases.