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Economics of natural disasters: from macro- to micro- evidence with a focus on developing countries

Tesi di Dottorato di Sara Lazzaroni

Matricola: 3911261

Anno Accademico 2012/2013

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Coordinatore: Chmo Prof. Luigi Campiglio

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This thesis is the result of an intense learning experience and adventurous journey in the understanding of world, household and individual dynamics. It has been written across ten countries starting from the Aula N of the Università Cattolica in Piacenza, through ISS library, on the tables of nice free Wi-Fi cafés, on buses, trains and planes. It was possible first of all thanks to the scholarship made available from the Università Cattolica and the great supervision from the professors that have accompanied me during these three years. Each of them has enriched me as a student and as a person, teaching me that the glass has always to be seen half full rather than half empty. So thanks to Marco Missaglia, Mariacristina Piva, Peter van Bergeijk, Arjun Bedi and Natascha Wagner.

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To my family

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List of Acronyms

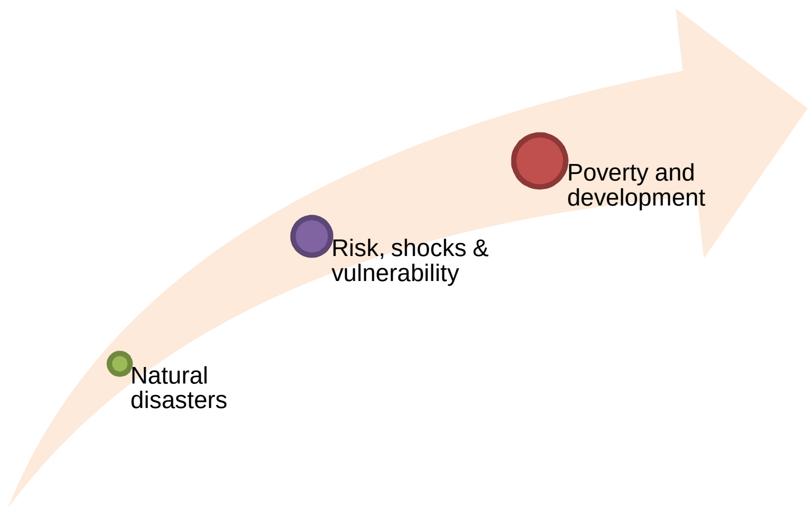
AGNSD	Agence Nationale de Statistique et Démographie of Senegal
CRED	Centre for Research on the Epidemiology of Disasters
DD	Difference-in-difference estimator
DDD	Triple difference estimator
GDD	Growing Degree Days
EM-DAT	Emergency Database
FAO	Food and Agriculture Organization
GIF	Global Index Insurance Facility
GOANA	Grand Agricultural Offensive for Food and Abundance
IFC	International Finance Group
IMF	International Monetary Fund
IPCC	International Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
LSMS	Living Standard Measurement Studies
NAPA	National Adaptation Plan of Action (Uganda)
NDP	National Development Plan (Uganda)
NEP	Nutrition Enhancement Program (Senegal)
UBOS	Uganda Bureau of Statistics
UNDP	United Nations Development Program
UNHS	Uganda National Household Survey
UNPS	Uganda National Panel Survey
UDOM	Uganda Department of Meteorology
WB	World Bank
WFP	World Food Programme
WHO	World Health Organization
WMO	World Meteorological Organization

Chapter 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). Hallegatte and Przyluski (2010: 2) define a natural disaster as "A natural event that causes a perturbation to the functioning of the economic system, with a significant negative impact on assets, production factors, output, employment, or consumption". The definition excludes endogenously initiated man-made disasters (Albala-Bertrand, 1993a: 8), however the intrinsic exogenous nature of natural disasters does not preclude that their impact is influenced by the socio-economic, demographic and institutional characteristics of the areas in which they occur. Hence, the economics of natural disasters is intertwined with the study of the determinants of poverty and development including the role of risk, shocks and vulnerability. Therefore the definition of the International Panel on Climate Change - IPCC (2012) special report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* as "Severe 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" seems more appropriated.

The quest whether disasters are a problem *of* or *for* development started with the seminal works of Albala-Bertrand (1993a; 1993b) who develops a model and provides 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 into three strands. First, researchers concentrated on the impact of single disastrous events on individuals and households with a microeconomic approach in order to understand the effects of natural disasters on specific welfare indicators. Household consumption, income and/or savings or health indicators such as height, weight and/or Body Mass Index (BMI) are some of the welfare indicators analyzed in the microeconomic literature on the effects of natural disasters (Dercon, 2004; Dercon and Krishnan, 2000; Kazianga and Udry, 2006; Maccini and Yang, 2008). Second and in a similar vein, the case studies analyses also focus on sectoral losses or losses from individual events (Benson and Clay, 2004; Vos et al., 1999; West and Lenze, 1994) using meso-economic models such as Input-Output and Computable General Equilibrium models to quantify and compare disaster effects in different sectors of the economy often considering specific disaster disruptions[1]. Third, due to the higher frequency and intensity of natural disasters and their relation to global warming, the empirical literature on the macro-economic impact of natural disasters has grown substantially during the last decade (Raschky, 2008). This third strand takes the lead from the previous two strands incorporating in the analysis some social, economic and institutional country-specific characteristics that were found crucial in determining the impact of natural disasters through their influence on households and governments' decisions (Noy, 2009). Ultimately acknowledging that "[D]isasters serve as reminders that progress is not linear and that development is characterized by discontinuities and dislocations of order" (Pelling et al., 2002), in this work I will attempt to shed some light on the relationship between natural disasters and development with an applied approach. First, I will evaluate the evidence at the macroeconomic level, and second I will provide some evidence concerning two specific case studies at the microeconomic level. The work is articulated in three main chapters followed by a concluding chapter summarizing the results and discussing some policy implications and further research needs.

Figure 1.1 Economics of natural disasters and its relationship to development.



Source: Author's elaboration.

[1] For example, Rose et al. (1997) and Rose and Liao (2005) analyze the regional impact of electricity lifeline and water service disruptions following an earthquake using an input-output and a computable general equilibrium model respectively.

Chapter 2 deals with the macroeconomic evidence on the impact of natural disasters providing a systematization and meta-analysis of the emerging macroeconomic literature on direct and indirect (secondary) costs of natural hazards. This literature originated in the years 2000s and accounts for about 44 studies. Although not widely used in economics, a quantitative meta-analysis is particularly suitable for the study of the impact of natural disasters because it helps to disentangle the effects of methodological choices by the authors on the results. Indeed, the assessed disagreement in terms of sign and level of significance of the impact throughout the studies could be due to empirical design (data source and time and regional disaggregations), estimation technique and resilience factors considered in the studies. Moreover, studies on the effects of natural disasters could suffer from publication bias, resulting in an overrepresentation of larger, more significant effects in the published research (Stanley and Docouliagos, 2012). The great advantage of meta-analysis results is the transparency and objectivity of the literature review strategy in contrast to narrative literature reviews.[2] Meta-analysis helps to emphasize where the research has concentrated and if publication selection is taking place, highlighting unexplored areas in need of further attention. The analysis in this chapter has important implications both in the formulation of policy-relevant documents such as the IPCC reports on natural extreme events and policy makers' decisions concerning long-run prevention and mitigation investments based on macroeconomic evidence (Bergeijk and Lazzaroni, 2013). In particular, the meta-regression results suggest that including African countries in the analysis increases by 65% the probability to find a negative and significant impact of natural disasters in terms of direct costs (number of people reported affected/killed or economic damages as a share of GDP). On the other hand, in indirect costs studies the inclusion of African countries in the disaster database seems to have no significant effects on the disaster outcome but indirect costs studies seems to be affected by publication bias. These result suggests the need to further explore the effects of natural disasters at the microeconomic level, Chapters 3 and 4 provide such microeconomic analyses focusing on two countries located in Sub-Saharan Africa.

To reconcile the macroeconomic and microeconomic literature on natural disasters some clarifications are needed on the terminologies that will be used throughout the following chapters. The IPCC classifies *natural (climate) extreme events* in simple extreme and complex extreme events (IPCC, 2001). Higher maximum and minimum temperatures (with the connected increase of hot days and heat waves) and the increase/decrease in the intensity and distribution of precipitation events are examples of extreme simple events. Increasing occurrence of droughts

[2] On the other side, limitations of quantitative meta-analyses can reside in the search strategy and the need to exclude qualitative and non-econometric studies as emphasized by Bergeijk and Lazzaroni (2013).

and floods, especially when precipitations are associated with El Niño events, or storms and tropical cyclones and more variability in the monsoon season are examples of extreme complex events. In the microeconomic literature natural extreme events are typically denominated *climatic shocks*. Within them Dercon et al. (2005: 5) include disturbances in the usual pattern of rainfall and temperatures (simple extremes in IPCC), droughts and floods (complex extremes in IPCC) and consider also other climate-induced distresses affecting crops and livestock such as pests and diseases. [3] Acknowledging the differences in intensity and origin of the three sub-categories of climatic shocks I will henceforth use the following terminologies

- *Climatic shocks* for natural and biological events in general, independently from their intensity
- *Weather variability* or *simple extreme events* for rainfall precipitation and distribution and temperatures variations with respect to the long-term pattern of weather indicators
- *Natural hazards* or *complex extreme events* for droughts, floods, frost, heat waves and wildfires
- *Biological hazards* for crop pests and livestock diseases.

Note that complex events can be considered nothing but simple extreme events that occur in a more disruptive way, due to their particular duration and temporal shape (Anderson, 1994: 555). In Chapter 3 I analyze the impact of simple extremes (weather variability) on households food consumption expenditures in rural Uganda. In Chapter 4 I study the impact of complex extreme events (droughts, extreme cold days) on child anthropometric characteristics in rural Senegal considering also the concomitance of natural disasters with shocks from the biological, economic and health sphere.

Chapter 3 takes the lead from the work of Dercon (2004) on shocks and growth in rural Ethiopia and studies the effects of weather variability in terms of millimeters of rain, number of rainy days and minimum and maximum temperatures on rural household food consumption expenditures. In line with the bulk of the literature on shocks and households vulnerability the analysis is conducted with a partial-shock approach, focusing on the particular set of climatic shocks selected without considering other shock categories.[4] The relationship between weather variations and food consumption in Uganda has not been yet widely explored, although the increasing concerns of food security in rural areas of the country, still dependent on rain-fed

[3] Dercon et al. (2005) mention other four shock categories: economic shocks accounting for abrupt changes in accessibility or prices of inputs and outputs on the market; political, social and legal shocks (conflicts, discriminations or disputes); crime shocks (theft and crimes towards the individuals); finally health shocks such as illnesses, epidemics and death.

[4] For completeness, in a second step the analysis was also conducted including other shock categories (crop pest, livestock disease, fire, death of the household head or other member, theft and conflict) showing robustness of results.

agriculture for their subsistence (Shively and Hao, 2012; Ssewanyana and Kasirye, 2010). The empirical analysis uses a dataset made publicly available by the Living Standard Measurement Studies division of the World Bank, while qualitative interviews and the analysis of recent developments in the agricultural sector help to underpin the results focusing on *ex-ante* coping strategies, ultimately framing a mixed methods analysis. The results of the econometric model suggest that although households in Uganda seem able to mitigate adverse variations of rainfall, they would be negatively affected by increases in maximum and minimum temperatures. Triangulating the findings of the econometric analysis with qualitative interviews and agricultural sector developments I argue that rural households in Uganda would be involved in *ex-ante* income smoothing strategies helping to partially offset the effects of weather variability. [5] Furthermore, the ability to insure against rainfall variations *ex-post* would partially depend on land ownership and reduction of other expenditures such as those for social events and outgoing remittances. Two reflections are further needed. First, the argued successful insurance strategy seems to apply only to the specific relationship between rainfall (precipitation and distribution) and food consumption expenditures at the household level. Although household consumption data are generally used to measure household living standards, results at this level of aggregation may mask different effects at the individual level depending on the intra-household allocation of resources. Second, consumption data have been shown to be particularly sensitive to changes in the survey design (method of recording, respondent level, length of the reference period and degree of detail in the commodity list) (Beegle et al., 2012). Sensitivity checks and further analyses on other indicators of household/individual welfare are then needed to better understand the effects of the phenomena of interest.

Starting from the reflections drawn in Chapter 2 and 3, Chapter 4 presents a multi-shock analysis focusing on the effects of complex extreme events (droughts) and increasing prices shocks on weight-for-age of children aged 12 to 60 months reported leaving in poor rural households in Senegal. Child anthropometric characteristics seem to provide a better test for consumption smoothing thanks to the higher reliability of the measurement strategy (Carter and Maluccio, 2003), hence this choice of dependent variable within a (less conservative) multi-shock analysis. I concentrate on rural households leaving in eight regions of Senegal thanks to a unique dataset covering the period 2009-2011 and including a rich shock module with data on natural, economic and health adverse events experienced by the households. Given the structural improvements occurring beteeen the survey rounds but the higher incidence of shocks in 2011, I

[5] Analyses of the overall household panel confirm the robustness of the results countrywide.

exploit difference-in-difference strategy to analyze the effects of droughts and inflationary periods. The results show that both shocks have negative effects on child weight-for-age, accounting for 50% (20%) of the child-weight-for-age standard deviation in 2011 in the case of a drought (an increase in purchasing prices). However, the analysis of conocomitant effects with triple difference estimations finds no significant effects on weight-for-age of children leaving in households that experienced both shocks. Further examinations of the channels through which drought and price shocks may affect child and household welfare suggest positive income effects driven by the two shocks concomitance for rural households.

As emerged from the discussion above, the main body of this work is structured in three different chapters. Although interlinked the three parts can be read independently. Each chapter is organized as follows. First, the particular subject, motivation and contribution are presented. Second, the analytical framework and literature are discussed. Third, background, data and empirical model are examined. Finally, results and main conclusions are provided.

Lastly, Chapter 5 summarizes the results of the main body of the three previous chapters and elaborates on their possible implications for policy purposes.

References

Albala-Bertrand, J.M. (1993a) *Political economy of large natural disasters with special reference to developing countries*. Oxford: Calendron Press.

Albala-Bertrand, J.M. (1993b) 'Natural Disaster Situations and Growth: A Macroeconomic Model for Sudden Disaster Impacts', *World Development* 21 (9): 1417–1434.

Anderson, C. (1994). The Aggregate Excess Measure of Severity of Extreme Events. *Journal of research of the National Institute of Standards and Technology* 99 (4): 555-561.

Beegle, K., J. De Weerdt, J. Friedman and J. Gibson (2012) 'Methods of household consumption measurement through surveys: Experimental results from Tanzania', *Journal of Development Economics* 98 (1): 3-18.

Benson, C. and E. J. Clay (2004) 'Understanding the Economic and Financial Impacts of Natural Disasters', *Disaster Risk Management Series* 4. Washington DC: World Bank.

Bergeijk, P.A.G. van and S. Lazzaroni (2013) 'Macroeconomics of Natural Disasters: Meta-analysis and Policy Options', Working Paper prepared for *Methods for Research Synthesis: A Cross-Disciplinary Workshop* (3-4 October). Cambridge, MA: Harvard Center for Risk Analysis.

Carter, M. And J.A. Maluccio (2003) 'Social capita land coping with economic shocks: An analysis of stunting of South African children', *World Development* 31 (7): 1147-1163.

Dercon, S. (2004) 'Growth and Shocks: Evidence from Rural Ethiopia', *Journal of Development Economics* 74 (2): 309-329.

Dercon, S., J. Hoddinott and T. Woldehanna (2005) 'Shocks and Consumption in 15 Ethiopian Villages, 1999-2004', *Journal of African Economies* 14 (4): 559.

Dercon, S. and P. Krishnan (2000) 'In Sickness and in Health: Risk Sharing within Households in Rural Ethiopia', *Journal of Political Economy* 108 (4): 688-727.

Hallegatte, S. and V. Przyluski (2010) 'The Economics of Natural Disasters'. Concepts and Methods.' *World Bank Policy Research Working Paper* 5507. Washington DC: World Bank.

IPCC (2001) *Climate Change 2001*: *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K. S. White (eds.)]. Cambridge, UK: Cambridge University Press.

IPCC (2012) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. (The SREX Report). Cambridge and New York: Cambridge University Press. Available at: <http://ipcc-wg2.gov/SREX/report/> Accessed 20 May 2013.

Kazianga, H. and C. Udry (2006) 'Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso', *Journal of Development Economics* 79 (2): 413-446.

Maccini, S.L. and D. Yang (2008) 'Under the weather: Health, schooling, and economic consequences of early-life rainfall', *NBER Working Papers Series* 14031. Cambridge, MA: NBER.

Noy, I. (2009) 'The Macroeconomic Consequences of Disasters', *Journal of Development Economics* 88 (2): 221–231.

Okuyama, Y. (2007) 'Economic Modeling for Disaster Impact Analysis: Past, Present and Future', *Economic Systems Research* 19 (2): 115–124.

Pelling, M., Ozerdem, A. and S. Barakat (2002) 'The Macro-economic Impact of Disasters', *Progress in Development Studies* 2 (4): 283–305.

Raschky, P. A. (2008) 'Institutions and the Losses from Natural Disasters.', *Natural Hazards Earth Systems Science* 8: 627–634.

Rose, A. and S. Liao (2005) 'Modeling regional economic resilience to disasters: A computable general equilibrium analysis of water service disruptions', *Journal of Regional Science* 45 (1): 75-112.

Rose, A., J. Benavides, S. Chang, P. Szczesnjak, and D. Lim (1997) 'The regional economic impact of an earthquake: Direct and indirect effects of electricity lifeline disruptions', *Journal of Regional Science* 37 (3): 437-458.

Ssewanyana, S. and I. Kasirye (2010) 'Food insecurity in Uganda: A dilemma to achieving the hunger millennium development goal', *Economic Policy Research Centre Research Series* 70. Kampala: EPRC.

Shively, G. and J. Hao (2012) 'A Review of Agriculture, Food Security and Human Nutrition Issues in Uganda', *Staff Paper* 12. Purdue, IN: Purdue University, Department of Agricultural Economics.

Stanley, T.D. and H. Docouliagos (2012) Meta-regression analysis in economics and business. New York: Routledge.

Vos, R., M. Velasco, and E. de Labastida (1999) 'Economic and Social Effects of El Niño in Ecuador, 1997-1998.', Inter-American Development Bank Technical Paper POV-107. IADB: Washington DC.

West, C.T. and D.G. Lenze (1994) 'Modeling the Regional Impact of Natural Disaster and Recovery: A General Framework and an Application to Hurricane Andrew', *International Regional Science Review* 17 (2): 121-150.

Chapter 2

Natural disasters impact, factors of resilience and development A meta-analysis of the macroeconomic literature[6]

Abstract

I systematize recent macroeconomic empirical literature on the direct and indirect impact of natural disasters and provide an ordered probit meta-analysis of 1255 t values reported in 44 primary studies published during 2002-2013. I classify the literature on the basis of the disaster costs studies analyzed in the primary studies (direct and indirect) and investigate how the reported results in the primary studies are influenced by the empirical design, the estimation technique, the resilience factors included in the analyses (GDP, education, institutions, population, investment) and/or publication bias. I analyze separately the primary studies on disaster direct costs and on indirect costs, respectively. In particular, for direct costs studies the probability the study reports a negative and significant impact is 65% higher if disaster data include African countries or consider long-term effects, while lower if more recent decades and/or Latin American Countries are included. Controlling for time and regional disaggregation, indirect costs studies have a 20% higher probability to report negative and significant results if they were published in a peer-reviewed journal, this showing publication rather than data bias. The meta-analysis also suggests that studies should explore more often the mitigation role of education, investment and openness.

JEL: O1; Q54, C25

Keywords: meta-analysis; natural disasters, development, growth, resilience, ordered probit.

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[6] This chapter benefits from the comments received from Peter van Bergeijk, Chiara Mussida, Maria Cristina Piva, Mario Veneziani, Gonzalo Delacámara, Reinhard Mechler, Jaroslav Mysiak, professors and participants at the Belpasso International Summer School 2013 on Environmental and Resource Economics (Belpasso, Italy, 1-7 September 2013), the conference MAER-NET in Greenwich (UK, 7-8 September 2013) and the workshop "Methods for Research Synthesis: A Cross Disciplinary Approach" (as invited paper, Harvard Center for Risk Analysis, Cambridge, MA, 3-4 October 2013) where the working papers were presented.

2.1 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 & Noy, 2010). Due to both the higher frequency and intensity of natural disasters and their relation to global warming, however, 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". In contradistinction to other definitions of natural disasters (see EM-DAT, 2011; Hallegatte and Przyluski, 2010) this definition clearly emphasizes the linkages between intrinsically exogenous natural hazards and the socio-economic, demographic and institutional characteristics of the areas in which hazards occur. Indeed, 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.

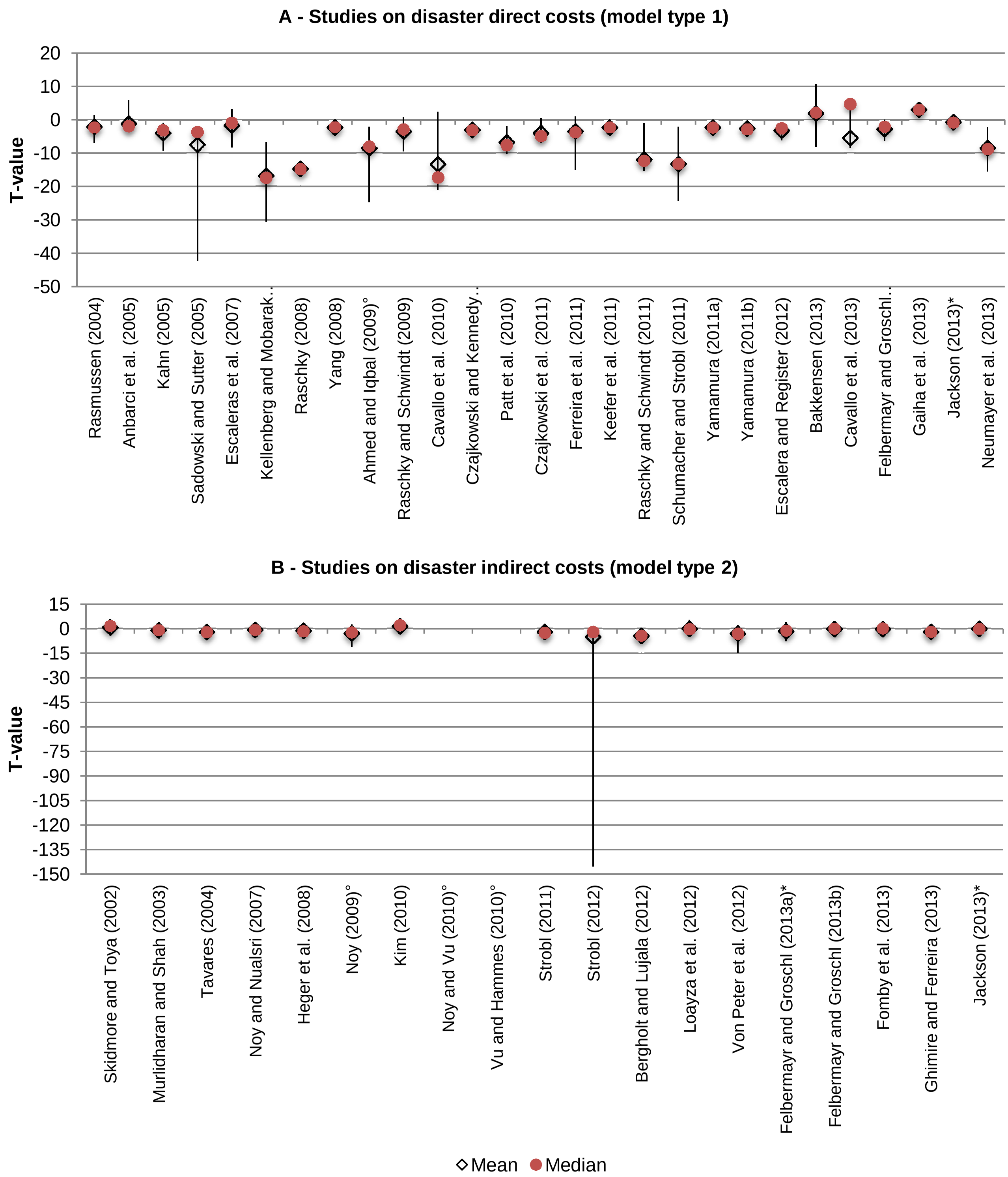
The quest whether disasters are a problem *of* or *for* development started with the seminal works of Albala-Bertrand (1993a; 1993b) who developed a model and provided empirical estimates that indicate that the long run growth impact of a disaster-induced capital loss is small, so that a moderate increase 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. Initially the approach was micro-econometric and/or case-specific. According to Noy (2009) the case studies and micro-econometric analyses substantiated the relevance of some social, economic and institutional country-specific characteristics in determining the macroeconomic impacts of natural disasters, in particular through their influence on households' decisions, thus clearing the way for the more recent macroeconomic analyses. This third level started to develop in the mid-2000s, is macroeconomic in nature and studies the economics of disasters from multi-country and/or multi-event perspectives. The debate in this macroeconomic literature focuses on the sign (positive or negative) of the impact of natural disasters and on the factors that mitigate this impact. I have identified 44 primary macroeconomic studies in the last decade that empirically try to assess the direct and indirect effects of natural disasters.[7] In Figure 2.1 I report the summary statistics of the collected t-values in the 44 primary studies in order to present an overview of the findings in the literature.[8] The median coefficient in direct disaster costs studies is positive in 3 cases and negative in 24 studies. The median impact on growth is positive in 4 studies and negative in 13 studies. Note that for two studies (Noy and Vu, 2010; Vu and Hammes, 2010) I do not report t-value aggregate statistics because they were presenting only p-values or symbolic representations of coefficients' level of significance. The average coefficient for direct costs studies is -4.40 and its standard deviation is 6.79, while the average coefficient for growth-disaster studies is -1.48, with a standard deviation of 6.14. Within the group of direct costs studies, nearly half report both negative and positive signs in the same study. Consistent negative sign in all collected estimates is found only in three indirect costs studies (Tavares, 2004; Bergholt and Lujala, 2012; Ghimire and Ferreira, 2013). Overall, natural disasters have an average t-value of -2.85 and a median t-value of -1.97. In line with the findings of the macro-econometric literature and with the results in the other strands, the IPCC (2012) recognizes the disagreement in the literature and assigns only *medium confidence*[9] to the dominance of negative disaster effects in the short-run.

[7] The cut-off date for the collected literature is December 2013. Note that two studies (Felbermayr and Groschl, 2013; Jackson, 2013) analyze both direct and indirect costs, so that the meta-dataset has 27 studies on direct costs and 19 studies on indirect costs.

[8] For ease of discussion I 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 I changed the sign of the parameters for the studies on disaster direct costs. The figure is based on data from Appendix Table A1.1 and A1.2.

[9] The IPCC Report assigns the degree of certainty in key findings 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.

Figure 2.1 Empirical studies on the macroeconomic impact of disasters (median and average reported t-statistics in 44 studies for the impact of disasters on direct and indirect costs).



Source: Authors' elaborations.

Note: See Appendix Table A1.2.

Note that several reasons may justify a positive or non-significant impact of natural disasters. First, as suggested by studies on disaster direct costs, some factors can help to mitigate the effects of a natural hazard (resilience factors). Disaster preparedness and mitigation may occur through education both in terms of access and lower vulnerability of educational facilities and access and sharing of disaster risk reduction knowledge (IPCC, 2012). Similarly, well-designed regulations in terms of building codes, identification and mapping of hazard zones, agricultural diversification, implementation of early warning systems and hazard information disclosure, and transparent and accountable institutions may help to lower exposure and vulnerability[10] (Rasmussen, 2004; Kellenberg and Mobarak, 2008; Raschky, 2008). Population density and size may play a role in determining disaster impact since exposure is high in more densely populated areas (Anbarci et al., 2005) although it can be argued that more people (also with their embedded human capital) may help in the reconstruction phase. These competing effects are common to other resilience factors such as openness, GDP and investment levels. Second, in connection with the discussion of resilience from GDP, investment and openness, some authors have put forward the Schumpeterian "creative destruction" argument (Skidmore and Toya, 2002; Kim, 2010; Loayza et al., 2012). After a disaster strikes, new technologies can be adopted and new capital can substitute the obsolete/damaged one to meet the needs of disaster management and reconstruction, this resulting in a net positive effect of the disaster. In an endogenous growth framework, decreasing returns to physical capital could foster human capital accumulation that in turn may lead to increasing returns to physical capital and investment simulating economic growth in high income countries and particularly promoting catch up in low income countries (Skidmore and Toya, 2002). Moreover, if the country where the disaster occurred is particularly open to the international community (in terms of diplomacy and trade), it may benefit from disaster aid and internationally led reconstruction activities whose positive effects could offset possible post-disaster short-term trade balance deterioration and capital flight (Heger et al., 2008; Noy, 2009)[11]. Note that the discussion is also linked to the time dimension of disaster occurrence in terms of immediate and long run disaster effects. I will discuss this in the following section. Third, insurance and reinsurance are often advocated as effective measures to

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[10] IPCC (2012: 559-564) defines exposure as "[t]he presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected" while vulnerability is defined as "[t]he propensity or predisposition to be adversely affected".

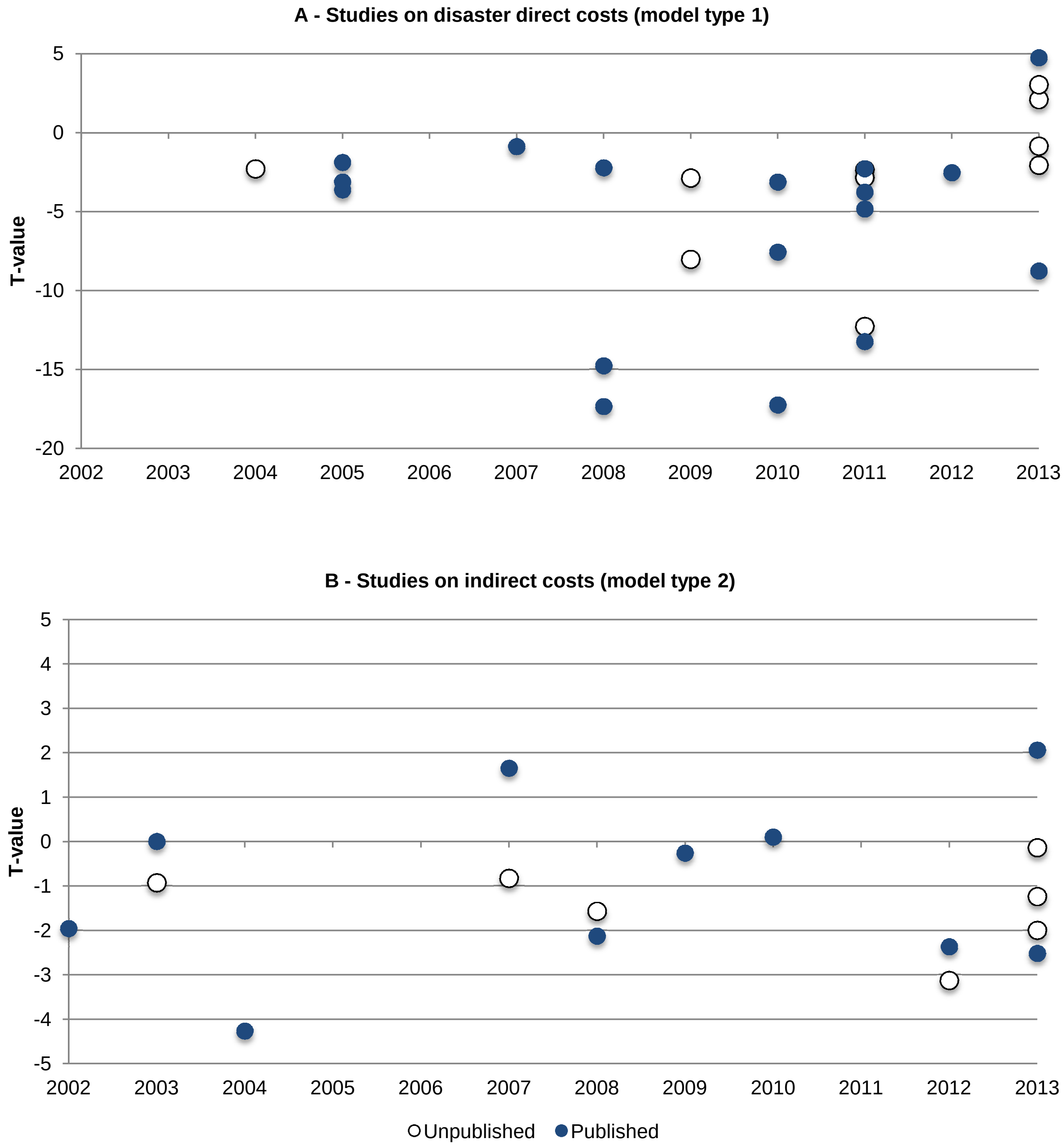
[11] The creative distruction argument has been investigated, among the others, by Albala-Bertrand (1993a), Okuyama (2003), Cuaresma et al. (2008) and Hallegatte and Dumas (2009). If Albala-Bertrand and Okuyama support the argument with growth theoretical models, the empirical analyses of Cuaresma et al. (2008) suggest that disasters would be more likely to have positive effects on developed economies only while the theoretical analysis of Hallegatte and Dumas (2009) conclude that poverty traps could also capture countries where reconstruction capacity cannot meet disaster damages.

reduce and/or offset disaster negative impact distributing risk over space and time and helping reconstruction (Rasmussen, 2004). Von Peter et al. (2012) test this hypothesis by measuring the effects of disaster on GDP growth while comparing the effects of insured and uninsured losses. The results of the empirical analysis suggest that uninsured losses would play a major role in lowering GDP growth both in the short and long run while insured losses would have no significant effects on GDP growth. However, the macroeconomic empirical literature explicitly considering insurance in the analysis is not well developed, the work by von Peter et al. (2012) being an exception. Finally, reporting errors or under-estimation of disaster losses may mask negative disaster effects, a discussion on the drawbacks of the most common disaster database is reported in other sections of the paper.

The debate is nowadays 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; Reed and Mercer, 2013; Toya and Skidmore, 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). Figure 2.2 shows the process of finding new results in both unpublished and published macro-econometric studies. Heterogeneity in the results is increasing over time both in the published and grey literature. Direct costs studies show prevalence of negative and significant disaster effects, but the most recent works progressively showing non-significant or positive results. Indirect costs studies present contradictory findings with published works generally presenting larger and significant median t-values.

A bias in the results is further suggested by screening the studies' funnel graphs in Figures 2.3 and 2.4. Funnel graphs plot all t-values on disaster impact drawn from the collected studies against their precision (the inverse of the t-values' standard errors). T-values with larger standard errors will be less precise and more dispersed at the bottom of the horizontal axis while more precise estimates will be at the top of the vertical axis with a more compact distribution (Stanley and Docouliagos, 2012). If no bias occurs, the funnel graph will be symmetric, otherwise possible sources of bias have to be identified – publication bias not necessarily leading per se to asymmetric funnel plots (Higgins and Green, 2011).

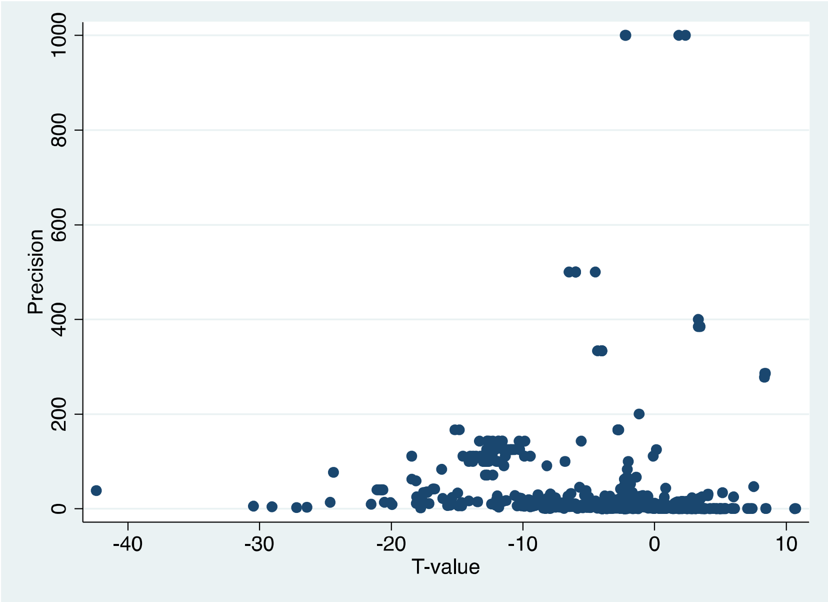
Figure 2.2 Median t-values of unpublished and published studies 2002-2013.



Source: Authors' elaborations.

Note: ° Noy and Vu (2010) and Vu and Hammes (2010) report only p-values or indicators of level of significance, hence these studies are missing in Panel B.

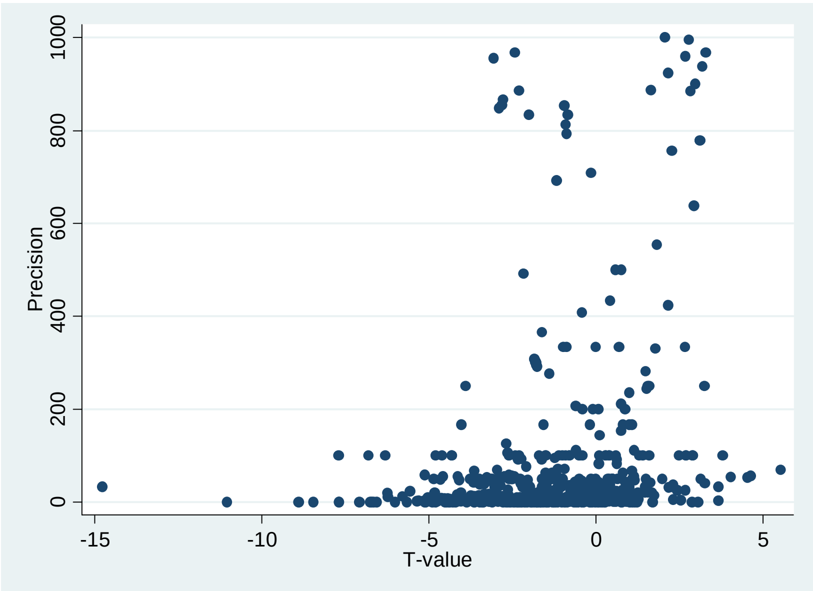
Figure 2.3 Funnel plot for t-values in studies on direct costs (model type 1).



Source: Authors' elaborations.

Note: 2 very extremely high precision values were excluded to allow better visualization of the graph.

Figure 2.4 Funnel plot for t-values in studies on indirect costs (model type 2).



Source: Authors' elaborations.

Note: 69 extremely high precision values (>1000) were excluded to allow better visualization of the graph with no major changes in its final shape of the funnel plot.

Disagreement and/or bias between studies concerning the sign and level of significance of disaster impact may be caused also by methodological differences as suggested by the apparent heterogeneity in the data, the 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 of methodology and publication selection on the reported results. The first contribution of this paper is that I provide such a meta-analysis relating the reported test statistics to the respective methodological and publication characteristics. Meta-analysis is a relatively new research technique in economics but is well accepted in other fields such as medicine and psychology. Recent examples in development economics include: Havránek and Iršová (2010), Doucouliagos and Paldam (2011), and Mebratie and Bergeijk (2013). The parameters that build the meta-dataset have been derived from studies that were identified in an extensive search of macroeconomic published articles, books, book chapters, working papers and conference papers as detailed in Section 2.3 and Appendix A2.

In this article I focus on the macroeconomic analyses because this part of the literature is more homogeneous. The microeconomic literature, for example, is very heterogeneous in terms of the study-specific research questions that reflect the manifold contexts and/or the investigated household coping strategies. It would, moreover, be difficult to combine the three levels because they use completely different indicators of disaster outcome. The case studies and the micro econometric analyses focus on sectoral losses or losses from individual events (Benson and Clay, 2004; Vos et al., 1999), consumption (Dercon, 2004; Kazianga and Udry, 2006) or health outcomes such as the Body Mass Index (Maccini and Yang, 2008; Dercon and Krishnan, 2000), while the macroeconomic studies concentrate on disaster damages in per cent of GDP, number of people affected and/or killed by the natural disasters and the effects of natural disasters on GDP.

As more clear in Section 2.2, relevant heterogeneity exists even within the relatively homogeneous subgroup of macroeconomic studies as the macroeconomic empirical literature quantifies the effects of natural disasters in terms of determinants of either direct disaster costs and/or the short/long-run growth effects of direct, indirect and secondary impacts (Cavallo and Noy, 2010). For the purpose of my analysis it is important to note that while fundamentally different, the determinants are at the same time highly interrelated. For this reason the studies of direct and growth effects of natural disasters are seen to be complementary in the understanding of the role of disasters during the process of development. Indeed as pointed out by Pelling et al. (2002: 285):

> "[…] 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)."

The literature on indirect impacts of disasters frequently refers to the literature on direct costs when motivating the empirical design of the studies. First, indirect and secondary effects of disasters ultimately derive from the frequency, magnitude and incidence of natural events, so that an indicator for direct disaster impact is always included in the empirical analysis. Second, findings of direct costs mitigation factors are often used to justify the inclusion of similar variables in the empirical model of the indirect impact. For example, Noy (2009) refers to Rasmussen (2004), Kahn (2005) and Toya and Skidmore (2007) to support the inclusion of political economy and income level variables. The second contribution of this chapter is that I clarify how and where the methodologies differ and how this affects the results reported in the literature.

The paper is structured as follows. Section 2.2 explores the existing macroeconomic literature on natural disasters and provides a classification of the 44 studies that make up the meta-analysis sample according to the main research questions and approaches in the analysis of disaster impacts. Section 2.3 describes the construction of the meta-dataset, introduces the dependent and explanatory variables and provides descriptive statistics. Section 2.4 presents and discusses an ordered probit analysis of the 1255 estimates that form the dataset. The empirical results show that empirical design and publication bias are highly relevant for the sign and level of significance of estimated disaster impact. In particular, for direct costs studies the probability the study reports a negative and significant impact is 65% (17%) higher if disaster data include African countries (consider long-term effects), while lower if more recent decades and/or Latin American Countries are included. Controlling for time period and regional disaggregation, indirect costs studies have 20% higher probability to report negative and significant results if they were published in a peer-reviewed journal, this showing publication rather than data bias. Section 2.5 concludes assigning *high confidence* to the negative effects of natural disasters, giving suggestions about the direction that future research in this field will have to take to further foster the knowledge on the effects of natural disasters.

2.2 Review of the macroeconomic literature on natural disasters

The macro econometric analyses focus on the effects of series of natural disasters investigating their 'mean' costs (Hallegatte and Przyluski, 2010). According to the ECLAC methodology, costs from disasters can be direct, indirect or secondary (Zapata-Marti, 1997: 10-11).

- Direct costs are 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 (Hallegatte and Przyluski, 2010).
- Indirect costs account for losses induced by disasters in terms of flows of goods, services and business revenues that will not be generated due to destructions or business interruptions (Hallegatte and Przyluski, 2010).
- Secondary effects are effects on the performance of the overall economy, quantifiable through the most relevant macro-economic variables in one or more years after the disaster occurred (Zapata-Marti, 1997: 10-11).

Albala-Bertrand (1993a: 11) argues that a disaster impact is a sudden and sharp imbalance between the forces of the natural system and the counteracting forces of the social system. In this vision the magnitude of the natural event is an important input to the system but the outcome in terms of vulnerability of people and activities and the severity of the disequilibrium would be determined by on the one hand, geophysical and/or biological processes and on the other hand, social processes.

2.2.1 Geophysical and/or biological processes

From the natural system point of view, disaster frequency, type and intensity seem to play a role in determining the final disaster outcome. To start with, some regions of the world seems to be more prone to experience extreme natural events, for example Central America and Caribbean and the United States are highly affected by hurricanes (Strobl, 2012; Czajkowski et al., 2011), while in general the Asia-Pacific region records the highest number of climatic and geological events (Cavallo and Noy, 2010; Padli & Habibullah, 2009). Hence, some authors explicitly consider the frequency of disaster as key disaster indicator when analyzing the determinants of disaster costs. Within direct costs studies Kellenberg and Mobarak (2008), Patt et al. (2010) and Rasmussen (2004) show that an increase in the number of natural disasters significantly increase the number of people reported affected/killed and the economic damages, with higher losses if the disaster is geological (earthquakes or land slides). By contrast, Anbarci et al. (2005), Cavallo et al. (2010) and Escaleras et al. (2007) find that on average countries that experience more disasters experience lower fatalities and damages. Escaleras et al. argue that this would be due to a learning process by the most affected countries allowing them to increase preparedness. Indirect costs studies present similar disagreement. For example, Heger et al. (2008) show that on average an additional disaster in the short-term reduces GDP growth by 24% while Skidmore and Toya (2002) considering long-term disaster effects show that higher frequency is positively correlated with growth in the case of climatic disasters but negatively correlated in the case of geologic disasters. Then, disaster type seems also to be an important factor. UNDP (2004: 3) proposes that earthquakes will affect those countries more strongly where urbanization is increasing, while tropical cyclones will be more harmful for countries with a higher share of arable land, and floods will be more damaging for countries with higher population density. Therefore temporal and spatial distributions of natural events determine disaster incidence, and therefore it is important to consider the criteria used to decide on the country and disaster samples in the studies.

Finally, the intensity of the disaster (in terms of Richter scale, wind speed or excess/lack of rain) also matters. Czajkowsky and Kennedy (2010) and Strobl (2012) on hurricanes, Ferreira et al. (2011) on floods and Anbarci et al. (2005) on earthquakes are some examples of studies finding higher deaths when disaster intensity is higher. However, some studies show insignificant effects of disaster intensity (Bakkensen, 2013; Felbermayr and Groschl, 2013a; Fomby et al., 2013) depending on disaster type, length of period considered and level of income of the countries in the sample. For instance, Fomby et al. (2013) find that in developing countries droughts have negative effects on GDP growth both in the short and long run while floods would have insignificant effects in the short-run but positive and significant effects in the long-term suggesting possible improvements in land productivity after a period of excess of water. When the authors consider only severe disasters, the effects of floods become insignificant probably due to the fact that damages from extremely intense floods are likely to exceed the gains from increased land fertility. Moreover, if the analysis is conducted on developed countries, both droughts and floods report insignificant effects on GDP growth both in the short and long run. The time dimension of disasters effects and the considerations on the role of initial wealth status bring the discussion to the socio-economic aspects of natural disasters.

2.2.2 Socio-economic processes

The socio-economic aspects of natural disasters consist of those factors that can foster the ability of affected countries to anticipate, mitigate and recover from natural hazards (resilience factors). Observations on the length of time considered in the analysis of the effects of natural disasters follow in the discussion of resilience factors since resilience capacity and effectiveness requires time to develop and carry out beneficial effects.

First, population size and density in areas prone to natural hazards have a crucial role in determining the level of exposure and most studies on disaster direct costs account for population characteristics in their analyses. For instance, Keefer et al. (2011) and Kellenberg and Mobarak (2008) find that countries with larger population experience higher mortality (more people exposed to the disaster). Escaleras et al. (2007) and Raschky and Schwindt (2009) include both population size and density in the analysis and show that population size seems to better explain disaster mortality but its effects would vary depending on disaster type. Czajkowski et al. (2011) and Raschky and Schwindt (2011) on mortality, and Sadowski and Sutter (2005) and Schumacher and Strobl (2011) on damages prefer to include population density in their analyses. Czajkowski et al. show that higher population density increases mortality while Raschky and Schwindt find lower disaster deaths as population density increases. The latter result may be due to higher preparedness of more densely populated areas thanks to better management of the territory, or higher awareness of residents about the best practices in case of disaster occurrence. On disaster damages Sadowski and Sutter and Schumacher and Strobl find increasing direct costs when population density increases (more exposure in terms of infrastructures and economic activities that can be affected in more populated areas). Turning to disaster indirect costs (effects on GDP), only few studies consider population size (Felbermayr and Groschl, 2013a, 2013b; Skidmore and Toya, 2002) and density (Ghimire and Ferreira, 2013; Heger et al., 2008), while two studies account for population growth (Jackson, 2013; Strobl, 2012) again presenting mixed results.

Second, countries/regions may be highly exposed but not vulnerable thanks to higher income levels, allowing better preparedness, mitigation and reconstruction capacity. For example, Rasmussen (2004) analyzing the Caribbean context suggests that increasing per capita income levels reduce both the number of affected and the economic damages from natural disasters. Rasmussen's results are also found in other relevant studies included in the meta-analysis (see for example Kellenberg and Mobarak, 2008; Escaleras and Register, 2012), indicating robustness of income effects on direct costs to differences in countries and time span included in the sample analyzed

Third, higher investment shares of GDP could allow lower disaster costs as investments in preventive measures may help to mitigate disaster impacts. Only one study on direct costs (Rasmussen, 2004) accounts for the share of investment in GDP, showing negative or non significant effects on the number of people reported affected and on economic damages. By contrast, investments do appear frequently in analyses of the (direct and indirect) effects of disasters on growth, often proving to be a positive and significant determinant of growth (see for example Kim (2010), Skidmore and Toya, 2002 and Strobl, 2012). Note that direct costs are measured upon disaster occurrence, hence countries with higher capital formation might be initially more exposed due to higher infrastructures density. On the other hand, in the medium/long-run, higher levels of investment could play a crucial role in fostering the recovery, even resulting in net positive disaster effects (as argued in the introductory section).

Fourth, higher levels of education allow people to take better decisions concerning their settlement in safer areas or safer building practices, thus reducing mortality (Toya and Skidmore, 2007; Yamamura, 2011a) and/or the possible negative effects on GDP (Loayza et al., 2012; Noy, 2009; Noy and Noualsri, 2007; Noy and Vu, 2010; Skidmore and Toya, 2002; Vu and Hammes, 2010). In the sample of primary studies, Yamamura (2011a) is the only study on direct costs considering education and supporting its mitigation effects on the negative and significant impact of natural disasters. Most indirect costs studies accounting for education report negative and non-significant disaster impacts while showing positive and significant effects of education (Noy, 2009; Noy and Vu, 2010; Skidmore and Toya, 2002; Vu and Hammes, 2010).

Fifth, openness could account for competition levels, possibility of technology transfer from abroad towards disaster risk reduction or higher disaster aid and reconstruction activities from the international community (Toya and Skidmore, 2007; IPCC, 2012). Few studies on disaster direct and indirect costs account for openness. Within direct costs studies, a generally negative and significant disaster effect is accompanied by a significant mitigation effect (or non significant effect) of increasing openness (Felbermayr and Groschl, 2013a; Raschky and Schwindt, 2009, 2011; Yamamura, 2011a, 2011b).

Sixth, the role of institutions. Kahn (2005) was the first to consider the role of institutions in mitigating disasters. Kahn argues that in more democratic countries, free media would allow higher government accountability, lower corruption and greater attention to disaster prevention and recovery. His findings suggest that more democratic countries experience lower death counts. Accounting for democracy, corruption and government effectiveness respectively, Keefer et al. (2011), Escaleras et al. (2007) and Raschky (2008) find similar results. In contrast, Yamamura (2011a, 2011b) shows a negative and significant effect of increasing democracy and a positive but non-significant effect of lower corruption levels, while other institutional characteristics (law and order, quality of government) show a positive effect on disaster deaths. Despite the increasing recognition of the role of institutions in fostering growth and development, institutions so far have been rather neglected in the growth-disaster analysis, although some studies acknowledge their potential to mitigate the impact of disasters (Bergholt and Lujala, 2012; Felbermayr and Groschl, 2013a, 2013b; Ghimire and Ferreira, 2013; Noy, 2009; Noy & Noualsri, 2007). Loayza et al. (2012) introduce institutions in the analysis claiming that their effects would be embedded in GDP initial level, share of investments, financial depth, government consumption to GDP, education and openness, but this would imply a redefinition of the concept of institutions in a too broad sense (in Section 2.3 and Table 2.4 I clarify the difference between institutions and institution quality indicators).

Finally, the discussion in this section has been permeated by considerations on the period of reference for the analysis. Indeed, being a natural event a sudden, potentially very destructive shock to the economy, the likelihood to find negative effects in the short-term is higher if the mitigation strategies put in place in the past by the actors in the economy were not up to the level of the destructive force of the natural hazard. Potentiated local observations systems, forecasting, interpretation and communication capacities can help to reduce disaster direct costs through timely alerts and evacuation interventions (Hallegatte, 2012). Hence, being indicators of preparedness in the short-term, resilience factors seem to be correlated to the effect of the disaster. However, besides the analysis of the effects of income and population levels only few studies on disaster direct costs explicitly consider other resilience factors in their analysis, suggesting that the resulting disaster impact in the short-term could be overestimated. This is not the case in disaster indirect costs studies where resilience is much more considered and where the evidence supports lower disaster effects in the long-run (Kim, 2008; Skidmore and Toya, 2002).

Hence, again it is the combination of both natural and physical-socio-economic systems that ultimately determines the severity of the disaster-induced imbalance and a meta-analysis is needed to better grasp the contribution of empirical design, estimation technique and resilience factors included on the results of the primary studies.

2.2.3 *Two literatures, two models*

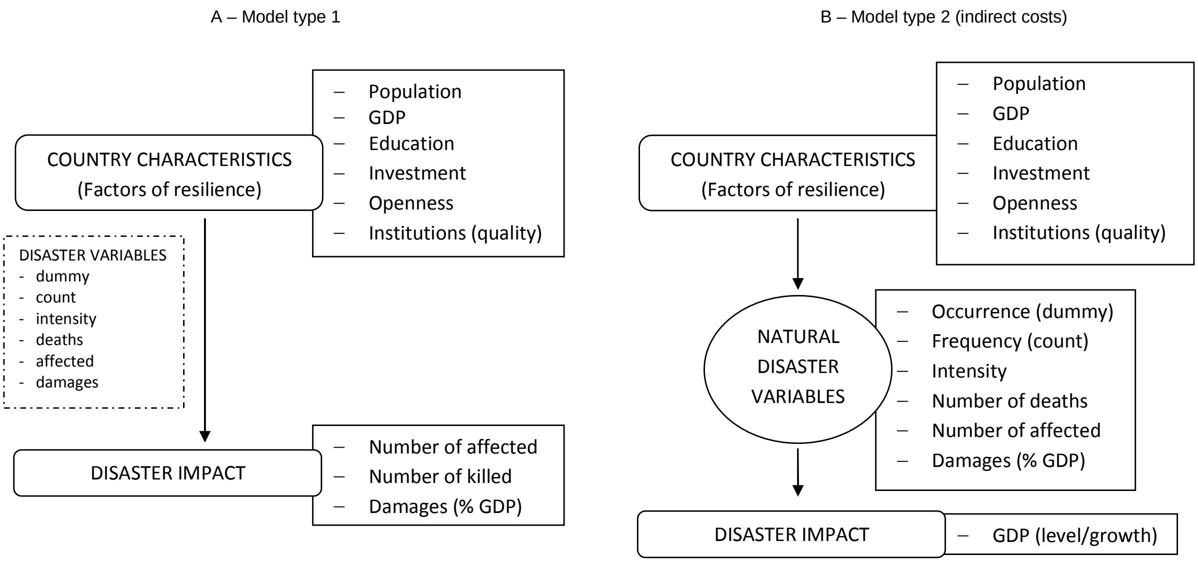
Building on the review above, I classify the studies according to the main research questions and approaches in the analysis of disaster impacts (Table 2.1). The first approach (model type 1) deals with direct costs of disasters, studying the role of socio-economic factors in mitigating or enhancing the adverse effects of disasters. Model type (1) studies usually focus on periods in which disasters actually occurred, mostly concentrating on disaster deaths and often including a disaster variable accounting for disaster occurrence (Raschky and Schwindt, 2009), frequency (for example Ahmed and Iqbal, 2009; Patt et al., 2010), intensity (for example Czaijkowski et al., 2011 and Schumacher and Strobl, 2012) or affected/killed population (for instance Ferreira et al., 2011 and Gaiha et al, 2013). The second approach studies the impact of natural disasters on GDP. It uses a specific 'disaster variable' that accounts for the occurrence of the phenomenon. The disaster variable can be a dummy, a disaster frequency or a variable describing the number of people affected or killed or the direct economic costs.

Table 2.1 Model type in the studies included.

Model		Research question
(1)	$DI_{it} = \alpha + \delta FR_{it} + u_{it}$	Disaster direct costs and resilience
(2)	$G_{it} = \alpha + \beta DV_{it} + \gamma FR_{it} + u_{it}$	Disaster indirect/secondary costs
i	Index to countries	
t	Index to time	
DI_{it}	Disaster damages, affected or killed	
G_{it}	GDP (level/growth rate)	
DV_{it}	Disaster variable (dummy, count, killed, affected, damages)	
FR_{it}	Factors of resilience	
u_{it}	Residuals	

Note: Greek letters are used to denote the estimated coefficients.

Figure 2.5 Model's structure in the selected studies.



Source: Author's elaborations.

As illustrated in Figure 5, model type (1) studies generally deal with disaster periods or situations and use as dependent variable the number of people reported affected or killed and/or the reported damages in the aftermath of a disaster. Disaster occurrence is indicated by a disaster frequency/intensity/severity variable (in the dashed rectangle). In contrast model type (2) compares periods or situations in which disasters occurred with periods or situations in which no disaster occurred. So the variables accounting for number of affected or killed and damages are a disaster impact variable in model type (1) and a disaster occurrence indicator in model type (2), the two models use common sets of explanatory variables.

One purpose of the meta-analysis is to correct for the differences in methodology and their impact and to distil the evidence that is in the 44 primary studies despite these differences. Although in practice cross referencing regularly occurs in the literature, I elaborated two meta-datasets and present results separately for studies on direct and indirect costs. For both model types the approach is straightforward and I collected the t-values corresponding to the disaster variable within the explanatory variables in regression results tables in the collected studies. Moreover, resilience factors are also deemed to be possible determinants of disaster final outcomes. To the extent resilience variables are correlated with disaster variables and with the final disaster outcome, they will contribute to both the magnitude and the level of significance of the disaster variable coefficient. If they are correlated with the disaster variable but not included as explanatory variables in the equation, the internal validity of the model will be compromised (due to under specification) and the estimators will be biased (Wooldridge, 2009: 90). In order to investigate this issue I collected t-values for the disaster variable and in the meantime I account for selected resilience factors included in the same specification thanks to dummy variables. For instance, in the work by Kellenberg and Mobarak (2008: 796) analyzing disaster direct costs in terms of deaths, specification (1) in Table 1 is (robust standard errors in parenthesis)

$$ln(KILLED_t + 1) = \underset{(0.023)}{-0.126} ln(GDPpc)_t + \underset{(0.024)}{0.325}\, ln(Tot.Pop)_t + \underset{(0.037)}{0.442}(\#ND)_t \quad (2.1)$$

In this case I calculate the t-value of the disaster count variable *#ND* as 0.442/0.037 = 11.9, I change its sign to allow comparison with growth studies (see note 2), and I give value 1 to the dummy variable accounting for the inclusion of GDP as a (resilience) control variable in the same regression (Res_GDP=1 referring to the included resilience variable $ln(GDPpercapita)_t$). I apply the same procedure for studies of model type (2). For example, Strobl (2011: 584) analyzing the growth impact of hurricanes from specification (2), reports the following equation (t-values in parenthesis)

$$GROWTH_{i,t-1\rightarrow t} = \alpha - \underset{(-2.509)}{0.0451} HURR_t - \underset{(-28.640)}{0.0523}\, log(INITIAL)_{t-1} \quad (2.2)$$

Based on this equation I record in the indirect costs meta dataset the t-value (-2.509) corresponding to the disaster variable (in this case $HURR_t$ a proxy of hurricanes intensity) while giving value 1 to the income resilience factor dummy as the specification includes initial income $log(INITIAL)_{t-1}$. The same procedure was applied to all other specifications in the tables in the primary studies.

2.3 Meta-analysis and meta dataset

I derive the parameters for the meta-dataset from 44 primary studies that I identified in an extensive search using Econlit and Google Scholar and deploying broad keyword listings with the following terminologies: 'natural disasters', 'impact', 'growth', 'economic development', 'development', 'killed', 'affected', 'institutions', 'econometric' [12]. Non-English studies and literature reviews were not included. Moreover, since I am interested in collecting coefficients

[12] This selection strategy is not immune to possible errors that might be driven by path dependence in searching engines or temporary unavailable research databases. To avoid these problems I conducted multiple searches since August 2012 up to December 2013 to ensure highest comprehensiveness of the meta-dataset.

and/or t-statistics of the variables considered, empirical works using vector autoregressive models and input-output analyses could not be included since the former reported the impulse response functions only and not the short and long-term coefficients (except for Fomby et al., 2013, duly included) while the results of the input output analyses by design do not provide the standard errors or t values needed for the meta analysis. Finally, I excluded the study of Moreno and Cardona (2011) because it is written in Spanish, while Benson and Clay (1998), Jaramillo (2009) and Simmons and Sutter (2005) were excluded because not reporting the number of observations in the estimations presented. Other studies on disaster direct costs were not included because lacking a disaster indicator in the explanatory variables, these studies have been stored and will be included in a future work analyzing specific resilience factors meta-effects. A schematic representation of the stages of the systematic review underlying the meta-analysis is reported in Appendix A2. The final 44 primary studies provide a total of 1255 estimates, 582 for type (1) studies and 673 for type (2) studies (including respectively 40 and 29 t-values inferred from p-values and results tables symbols such as asterisks for parameter level of significance).

This section first discusses the variables included in the meta dataset and then sets out the econometric approach that followed in the meta analysis.

2.3.1 Dependent variable: t-values of direct and indirect disaster effects

Since both the research question and the model specification (log-log, linear-log, log-linear, linear) used across the studies are different and because the necessary information to derive comparable elasticities is often not reported in the studies, the analysis is conducted on the reported t-statistics. This has the advantage that t-values are dimension-less and hence more comparable. Since the major discussion in the literature is about sign and significance the focus on t statistics is appropriate.[13]

Appendix Table A1.1 and A1.2 list the studies included in the meta-dataset, their major characteristics being illustrated in Figure 2.1. The variability in the number of observations and level of significance of the mean/median collected t-statistic across the selected studies is evident. As noted before, this variability could be the result of different choices in the empirical design and modeling such as database used, number of countries considered, length of the reference period of time, panel structure of the data, model type, estimation methodology, resilience factors etc. Heterogeneity is high both between and within studies thanks to the robustness checks carried out with different methodologies and database subsamples. Since the

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

majority of the studies do not explicitly define a preferred econometric specification I choose to collect the t-values from all the regression results presented in the selected studies, while I control for study dependence by clustering standard errors by study and applying different weighting schemes to account for studies with a high number of t-values. Before discussing in depth the meta-analysis' empirical strategy in Section 2.4, I take a closer look at the dependent variable. Composite t-statistics are computed for some of the variables that will be used as moderator variables (sources of heterogeneity in the results of the studies). In doing this I follow the approach of previous meta-analyses (Sinani and Meyer, 2009; Havránek and Iršová, 2010 and Mebratie and van Bergeijk, 2013) and calculate the composite t-statistic as

$$t_C = \sum t_i / \sqrt{N} \sim N(0,1) \qquad (2.3)$$

Indeed, the precision of a population parameter increases in sample size. So by enlarging the group of primary studies and using the information contained in their samples, the combination of the individual studies is expected to generate a more significant result (a t-value that differs more from zero, either positively or negatively). In light of the variability of the number of observations from the selected studies, it is important to follow Diebel and Wooster (2010), Djankov and Murrell (2002) and Mebratie and van Bergeijk (2013), and calculate a weighted composite statistic

$$T_{WC} = \sum_{k=1}^{n} w_k t_k \Bigg/ \sqrt{\sum_{k=1}^{n} w_k^2} \sim N(0,1) \qquad (2.4)$$

where $\boldsymbol{w_k}$ is the weight assigned to the n^{th} t-value in the meta-dataset calculated as the reciprocal of the number of t-values from the same study. Table 2.2 presents the composite and weighted t-statistics. Calculations were also conducted excluding extremely high t-values (>10) for a remaining number of 448 and 640 t-values for model type (1) and (2) studies respectively.

Table 2.2 Composite t-statistics of the selected studies.

Composite t-statistics [a]	Using median t-values from each study		All observations		Excluding outliers		Weighted all observations		Weighted excluding outliers	
	T_C	N	T_C	N	T_C	N	T_{WC}	N	T_{WC}	N
Model type [b]										
(1) – neg	33.15	27	141.69	425	67.55	308	80.13	425	43.14	308
(1) – pos	4.56	9	36.52	138	34.95	136	12.61	138	10.78	136
(2) – neg	9.21	17	56.88	451	48.52	447	36.59	451	32.50	447
(2) – pos	4.40	14	18.83	181	18.83	181	14.37	181	14.37	181
Database: EM-DAT										
(1) – neg	29.71	18	140.15	284	57.18	175	68.23	284	33.40	175
(1) – pos	1.81	3	3.02	9	3.02	9	2.89	9	3.24	9
(2) – neg	7.48	13	32.47	212	31.79	211	27.90	212	27.60	211
(2) – pos	4.24	11	14.75	109	14.75	109	12.30	109	12.29	109
Database: Other										
(1) – neg	12.07	9	47.09	141	37.20	133	44.42	141	32.96	133
(1) – pos	4.30	6	36.97	129	35.37	127	12.80	129	12.45	127
(2) – neg	6.31	7	47.55	239	36.72	236	23.87	239	18.42	236
(2) – pos	2.38	6	11.71	72	11.71	72	7.76	72	7.75	72
Use panel data										
(1) – neg	30.37	24	140.02	397	63.52	281	89.89	397	43.74	281
(1) – pos	4.53	8	35.66	123	34.02	121	12.57	123	10.40	121
(2) – neg	9.18	15	56.64	430	48.09	426	36.15	430	32.00	426
(2) – pos	3.29	12	13.59	143	13.59	143	9.85	143	9.85	143
Use cross-section data										
(1) – neg	7.94	4	24.73	28	23.20	27	11.48	28	11.15	27
(1) – pos	1.88	2	8.63	15	8.63	15	2.89	15	2.90	15
(2) – neg	1.72	2	7.26	21	7.26	21	5.69	21	5.69	21
(2) – pos	3.59	2	14.75	38	14.75	38	12.18	38	12.18	38
Resilience: GDP										
(1) – neg	30.10	22	141.61	339	61.77	224	88.15	339	40.81	224
(1) – pos	4.75	8	36.99	133	35.41	131	12.58	133	10.72	131
(2) – neg	9.14	14	46.79	359	45.04	356	30.17	359	29.35	356
(2) – pos	4.14	10	14.98	97	14.98	97	10.22	97	10.23	97
Resilience: Education										
(1) – neg	3.24	2	6.18	10	6.18	10	5.26	10	5.26	10
(1) – pos	-	-	-	-	-	-	-	-	-	-
(2) – neg	3.75	4	13.11	71	13.11	71	13.09	71	13.07	71
(2) – pos	3.18	4	13.22	45	13.22	45	13.40	45	13.40	45
Resilience: Investment										
(1) – neg	2.40	1	4.89	4	4.89	4	4.89	4	4.89	4
(1) – pos	1.36	1	1.93	2	1.93	2	1.93	2	1.93	2
(2) – neg	7.78	10	37.35	232	36.05	230	28.72	232	27.83	230
(2) – pos	4.79	9	13.52	94	13.52	94	10.41	94	10.42	94
Resilience: Openness										
(1) – neg	12.59	4	34.37	54	30.20	51	15.60	54	16.39	51
(1) – pos	0.83	1	0.83	1	0.83	1	0.83	1	0.83	1
(2) – neg	7.49	12	35.69	275	34.48	273	31.05	275	30.00	273
(2) – pos	3.77	9	15.35	118	15.35	118	14.13	118	14.12	118
Resilience: Population										
(1) – neg	30.40	21	134.53	363	61.90	257	87.23	363	41.02	257
(1) – pos	4.68	6	37.64	124	36.02	122	13.11	124	10.62	122
(2) – neg	18.52	8	28.23	160	27.44	159	12.43	160	12.10	159
(2) – pos	6.67	5	9.20	56	9.20	56	7.82	56	7.81	56
Resilience: Institutions										
(1) – neg	13.33	11	94.11	184	46.19	123	47.47	184	34.40	123
(1) – pos	1.56	3	3.59	11	3.58	11	4.23	11	4.24	11
(2) – neg	6.04	6	31.99	156	31.21	155	13.76	156	13.42	155
(2) – pos	1.42	3	6.77	37	6.77	37	4.87	37	4.86	37

(Continued)

(Continued)										
Published										
(1) – neg	114.0	16	107.46	181	44.92	128	77.64	181	35.48	128
(1) – pos	7.73	4	6.17	10	6.28	10	5.61	10	5.44	10
(2) – neg	20.77	10	46.06	223	36.48	267	38.99	223	32.54	267
(2) – pos	9.67	8	16.69	209	16.69	109	14.35	209	14.35	109
Not published										
(1) – neg	48.27	11	94.44	244	50.48	180	32.39	244	24.70	180
(1) – pos	5.95	5	36.16	128	34.55	126	14.67	128	13.97	126
(2) – neg	17.19	7	34.43	228	33.53	227	15.04	228	16.61	227
(2) – pos	6.80	6	9.32	72	9.32	72	6.31	72	6.31	72

Source: Authors' elaborations.

Note: [a] In the table T_C stands for composite unweighted t-statistics as explained by equation (1) in the text while T_{WC} stands for composite weighted t-statistics as explained by equation (2) in the text. [b] In the table (1) stands for Model type 1 while (2) stands for Model type 2. Grey cells highlight relevant information for discussion.

Table 2.2 presents unweighted and weighted statistics providing insights on the analysis of the reported t-statistics. First, the composite t-statistics are always statistically significant (except in the case of positive t-values for model type (1) accounting for openness). This result also holds when I exclude outliers, is independent of model type and does not depend on publication status. However, the significance decreases substantially when I use one observation per study (the median). Second, negative composite t-statistics are always more significant than their positive counterparts, but the weighted statistics are always lower than the unweighted ones. This suggests that it is necessary to use a weighting scheme that takes the number of regressions per primary study into account. Third, extreme t-values seem to drive higher composite (negative) statistics, suggesting that some studies may include particularly negative results ultimately influencing the reported average outcome[14]. Composite t-statistics further support the argument that methodological choices could have a bear on the results in the collected studies. For example, for model type (1) studies using EM-DAT negative composite t-statistics are influenced by outliers but clearly show negative disaster impacts. Similarly, while the choice of panel analyses seems to provide more significant negative disaster effects for model type (2), cross sectional studies show more significant positive disaster indirect effects. The main observation concerning the inclusion of resilience factors in the analysis is that some of them are rather neglected by the literature. For instance, only few studies on direct costs include education, investment and openness.

[14] For direct costs studies outliers were found in Ahmed and Iqbal (2009), Bakkensen (2013), Cavallo et al. (2010), Czajkowski and Kennedy (2010), Ferreira et al. (2011), Kellenberg and Mobarak (2008), Neumayer et al. (2013), Patt et al. (2010), Raschky (2008), Raschky and Schwindt (2011), Sadowski and Sutter (2005) and Schumacher and Strobl (2011). For idirect costs studies outliers were in Noy (2009), Strobl (2011) and von Peter et al. (2012).

2.3.2 Explanatory variables

The heterogeneity in the results of the studies on the impact of natural disasters could be due to four methodological choices:

- model type (focusing on disaster direct or indirect costs),
- empirical design of the primary study (database, disaster type, period and space choices to delimitate the subsample for the analysis),
- controlling variables considered in the primary study (including resilience factors),
- econometric estimation technique.

As mentioned in Section 2.2 I deal with studies on direct and indirect costs separately to allow higher comparability between the primary studies.

Disaster data

The EM-DAT dataset is the dominant data source of the primary studies (more that 70% of the studies use this dataset). Eight studies (30%) on direct costs (Bakkensen, 2013; Ferreira et al., 2011; Neumayer et al., 2013; Anbarci et al., 2005; Escaleras et al., 2007; Sadowski and Sutter, 2005; Czajkowski and Kennedy, 2010; Czajkowski et al., 2011) and four studies on indirect costs (24%) (Jackson, 2013; Ghimire and Ferreira, 2013; Strobl, 2011; von Peter et al., 2012) used databases other than EM-DAT. Three studies conduct the analysis comparing the results using different disaster datasets (Skidmore and Toya, 2002; Strobl, 2012; Felbermayr and Groschl, 2013a), Table 2.3 reports further details on the different databases. As revealed by composite t-statistics the database used could have influenced the result of the studies, hence I include a dummy in the meta-equation assuming value 1 if the study was conducted using EM-DAT, and 0 otherwise.

Table 2.3 Databases with information on natural disasters used in the selected studies.

Database	Studies by model type (1)	(2)
EM-DAT	Rasmussen (2004) Kahn (2005) Kellenberg and Mobarak (2008) Raschky (2008) Yang (2008) Ahmed and Iqbal (2009) Raschky and Schwindt (2009) Cavallo et al. (2010) Raschky and Schwindt (2011) Schumacher and Strobl (2011) Yamamura (2011a) Yamamura (2011b) Patt et al. (2013) Keefer et al. (2011) Escaleras and Register (2012) Cavallo et al. (2013) Felbermayr and Groschl (2013a) [a] Gaiha et al. (2013) Jackson (2013) [a]	Skidmore and Toya (2002) [b] Murlidharan and Shah (2003) Tavares (2004) Noy and Noualsri (2007) Heger et al. (2008) Noy (2009) Kim (2010) Noy and Vu (2010) Vu and Hammes (2010) Bergholt and Lujala (2012) Loayza et al. (2012) Strobl (2012)* Felbermayr and Groschl (2013a) [b] Felbermayr and Groschl (2013b) Fomby et al. (2013)
EM-DAT, Nordhaus (2010)	Bakkensen (2013)	
NOAA, NMFC/JTWC, GPCP, USGS		Jackson (2013) [a]
Davis (1992)		Skidmore and Toya (2002) [b]
Dartmouth Flood Observatory's (DFO)	Ferreira et al. (2011)	Ghimire and Ferreira (2013)
HURDAT		Strobl (2011)
HURDAT, Eastern North Pacific Tracks File		Strobl (2012) [b]
Munich Re	Neumayer et al. (2013)	Von Peter et al. (2012) Felbermayr and Groschl (2013a) [a, b]
NGDC	Anbarci et al. (2005) Escaleras et al. (2007)	
NHC Annual, NHC Tropical	Sadowski and Sutter (2005) Czajkowski and Kennedy (2010)	
Rappaport (2000), Czajkowski and Kennedy (2010)	Czajkowski et al. (2011)	
Total*	27	19

Source: Authors elaborations on the selected studies.

Notes: [a] Felbermayr and Groschl (2013a) and Jackson (2013) analyze both direct and indirect costs. [b] Felbermayr and Groschl (2013a), Skidmore and Toya (2002) and Strobl (2012) conduct the analysis comparing different datasets.

Disaster type

The type of the disaster investigated could have influenced the results across the studies in the sample since different studies accounted for different types of disasters. For example, according to Cavallo et al. (2013), on average, increasing intensity of earthquakes and storms would increase direct costs (deaths and economic damages), earthquakes being more harmful than storms. Similarly on long-term indirect costs, Skidmore and Toya (2002) find that climatic events such as floods, hurricanes and storms would be positively correlated with long term growth while geological disasters like earthquakes and volcano eruptions would be negatively correlated. Disasters are classified in three broad categories (the third one accounting for non-natural disasters that were sometimes included in the analyses) and I set up respective dummy variables to consider if the collected t-value refers to a specific disaster category (the base category is no disaster occurrence). Climatic disasters include floods, droughts, extreme temperature events, windstorms, hurricanes and wet mass movements. Geologic disasters include earthquakes, landslides, volcano eruptions, dry mass movements. Famines, epidemics, wildfires and economic disasters form the "other" category.

Sample size

The samples used in the studies account on average for 1,206 (1606) observations for direct (indirect) costs studies but the variability in the number of observations is very high: the standard deviation is 1,270 (2,233) observations, with a minimum of 18 (36) and a maximum of 9,326 (14,724) observations. The number of observations could have a specific effect on the likelihood to obtain a certain sign and/or level of significance for the t-statistics reported in the studies, hence I included this variable in the meta equation.

Period

I set up a set of dummies to account for the period of time covered by the primary studies (the dummies indicate decades: 1940s, 1950s, 1960s, 1970s, 1980s, 1990s and 2000s; since only one study included 1940s and 1950s I use these decades as reference category). In fact, according to Cavallo and Noy (2010: 9-10) analyzing the EM-DAT dataset, the reported incidence of natural disasters has increased over the last four decades, independently from the area of the world considered, especially due to an improved recording of smaller disasters. Hence, once I account for the period of time considered by the study, the non-significance of the estimated impact of natural disasters could be due to the higher frequency of smaller disasters in the sample as the time period studied in the primary studies approaches more recent years. Note that the overall length of the period considered should also incorporate part of this change in the composition of the disaster dataset. Therefore I will use these two different strategies to assess if the hypothesis of correlation between the time period considered and magnitude and significance of results is confirmed. I use two dummies for the length of the disaster impact analysis (medium or long); the short run is the reference category. This accounts for the argument that in the short-term disasters could have a negative impact while in the long term the economies would be able to recover, with the disaster potentially generating positive effects on growth (Skidmore and Toya, 2002; Kim, 2010; Loayza et al., 2012).

Countries and regions

I include in the meta-analysis dummies for six regions, namely, Africa, Asia, Europe, Latin America and the Caribbean, North America and Oceania. As will be clarified in the following section, not all the primary studies report the number and list of countries included (or excluded), lowering the quality of the findings in terms of interpretive power, generalizability and replicability.

Resilience factors

As discussed, the models used in the empirical macroeconomic literature on the effects of natural disasters account for different factors that can influence the impact of disasters on the outcome variable. In the selected studies I identified six main factors: indicators of wealth (GDP and/or income in level or growth rate), indicators of the level of education in the country, the investment share of GDP, indicators of the degree of openness, indicators of institutional/democracy qualities and variables accounting for the population (size and/or density) in the country. A dummy with value one if the factor was included in the model specification and zero otherwise has been created for every factor (Table 2.4 summarizes their use and measurement).

Estimation technique

Different studies use different econometric estimation techniques, often also within the same study, depending on the disaster outcome considered and discussing the suitability of different estimation techniques and showing how robustness/differences in the results depend on the chosen strategy. Model type (1) studies generally concentrate on the number of people reported killed or affected. Some authors argue that OLS would be inappropriate because the dependent variable is an over-dispersed and strictly non-negative count variable (Anbarci et al., 2005; Keefer et al., 2011; Raschky and Schwindt, 2009). Moreover, if the dependent variable is "damages", problems may arise from the presence of outliers and the stronger effects of disaster propensity at the top end of the conditional disaster damage distribution (Neumayer et al., 2013). Nevertheless, Khan uses OLS (regressing "deaths" on "number of disasters") addressing

Table 2.4 Factors of resilience and their measurement across the selected studies.

		Model type	
Resilience factor	Indicator	(1)	(2)
GDP	Lagged GDP per capita growth rate (log/level)	0	3
	Lagged GDP growth rate (log/level)	0	3
	Beginning of the period log real per capita GDP	3	3
	Current GDP per capita	20	9
	Income per capita	2	1
Education	Illiteracy % population	0	1
	Years of secondary and higher schooling in the male population aged 15 and over at the beginning of the period	0	1
	Years of secondary and higher schooling in the total population aged 15 and over at the beginning of the period	0	1
	Log initial ratio of number of students enrolled in secondary school to the no. of persons of the corresponding school age	0	1
	School enrollment % population	0	2
	Years of school attainment	1	0
Investment	Lagged gross capital formation % GDP (WDI)	0	4
	Investment ratio over real GDP	1	6
	Growth in capital stock per capita (Kind Levine, 1994)	0	1
Openness	Import plus export over GDP (level/log)	4	8
	Domestic trade (% output)	0	1
	Open economy index (Sachs Warner, 1995): 1=open economy	1	3
	Open economy index (Sachs and Warner, 1995; Wacziarg and Welch, 2008)	0	1
	Exports of goods and services	0	1
Population	Number of inhabitants (level/log)	14	2
	Population growth rate	0	2
	Density (population/squared Km	12	2
Institutions	ICRG political risk rate: 0=bad, 100=good	0	2
	ICRG investment climate: 0=bad	1	0
	ICRG government stability: 0=bad	1	0
	ICRG quality of government: higher=better	2	0
	ICRG quality of legal system	1	0
	ICRG corruption: 0=bad, 6=good	2	0
	Polity II democracy index: -10=low, +10=high	3	1
	Polity III democracy index	1	0
	Polity IV democracy index: 0=low, 1=high	0	1
	Polity IV democracy index: 0=low, 10=high	3	1
	Polity IV democracy index: 0=low, 20=high	1	1
	(Kaufmann et al., 2003) Regulatory quality: 0=low, 1=high	2	0
	(Kaufmann et al., 2003) Voice and accountability: 0=low, 1=high	2	0
	(Kaufmann et al., 2003) Political stability: 0=low, 1=high	1	0
	(Kaufmann et al., 2003) Rule of law: higher=better	2	0
	(Kaufmann et al., 2003) Control of corruption 0=low, 1=high	2	0
	Transparency International corruption index: 1=most c., 10=least c.	1	0
	World Bank government effectiveness index:	1	0
Total		27	19

Source: Authors elaborations from the selected studies.

over-dispersion using the logarithm on the number of deaths[15] and showing robustness of the results when applying instrumental variables (IV) and negative binomial techniques. Others prefer the Zero Inflated Negative Binomial – ZINB (Ahmed and Iqbal, 2009; Czajkowsky and Kennedy, 2010; Czajkowski et al., 2011; Raschky and Schwindt, 2009; Yamamura, 2011a). ZINB assumes that two processes underlie the data analyzed: in the first the probability that some observations are zeros would be 100%, while in the second the probability to report non-zero outcome is not nil. According to Keefer et al. (2011) the existence of the first process might be questionable depending on the degree of exposure and vulnerability of the countries included in the sample, thus invalidating the appropriateness of ZINB. Model type (2) studies concentrate on the effects of disasters on GDP growth (level), hence negative binomial and ZINB are not appropriated. About half of the t-values collected were estimated using OLS while more recent studies try to address possible endogeneity issues using Generalized Method of Moments – GMM or IV approaches. However, both Hager et al. (2008) and von Peter et al. (2012) show no major differences in results from OLS and GMM. IV is generally applied when the author wants to specifically address a specific issue (see for example Felbermayr and Groschl, 2013b focusing on the effects of trade or Jackson, 2013 considering disaster aid). Finally, for both model types authors debate whether or not to include country fixed effects. One the one hand, country fixed effects help to rule out unobserved heterogeneity including historical and cultural factors while emphasizing the within-country change stemming from income growth over time (included in the control variables) (Felbermayr and Groschl, 2013; Kellenberg and Mobarak, 2008). On the other hand, Toya and Skidmore (2013) argue that unobserved cross-country (and time) variation has to be retained since disaster preparedness in each country increases following each internal (slow) process of development. Accordingly, I set five dummies for estimation techniques (OLS, GMM, IV, negative binomial, ZINB, other techniques being the reference category) and one dummy to account for the inclusion of country fixed effects.

Publication bias

In light of the considerations stemming from Figures 2.3 and 2.4 in the introductory section and the composite t-statistics in Section 2.3, I introduce a dummy to take into account if the study was published in a peer-reviewed journal (value 1) or not (value 0). Broadly speaking, published studies should be of higher quality, however publication may also be influenced by authors' and journals' biases to report more extreme results (as suggested by Figure 2.2) or outcomes that fit

[15] An arbitrary small number was added in order to allow the logarithmic transformation to be defined (and the observations retained) also when a disaster reported no deaths.

their conceptions on the phenomena analyzed (for example towards a negative perception of disaster effects).

2.3.3 Descriptive statistics

Table 2.5 reports the definition and descriptive statistics of all the explanatory variables in the meta-dataset: empirical design, resilience factors and estimation technique variables.

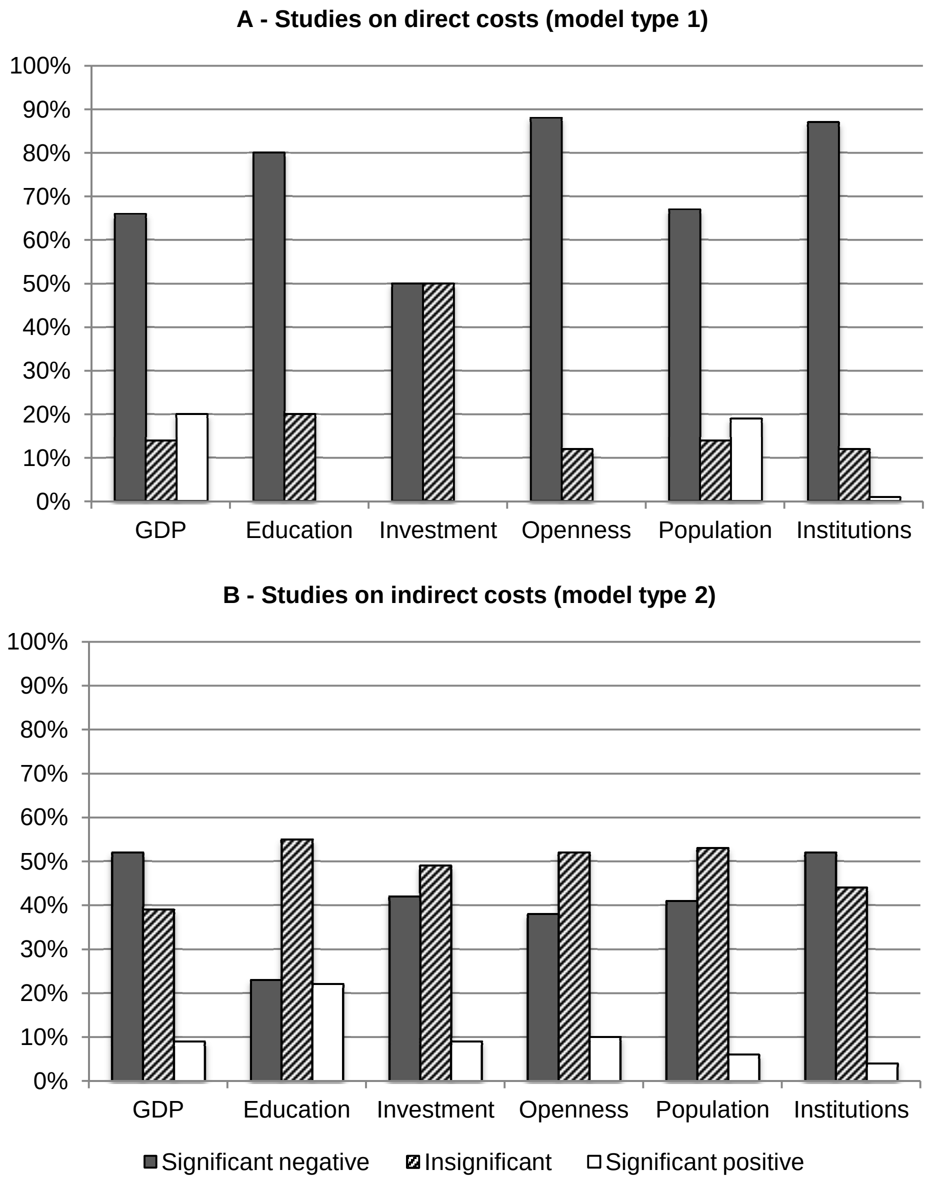
Table 2.5 Definition of variables and descriptive statistics.

			(1)			(2)	
Variable	Description	N	Mean	St.D.	N	Mean	St.D.
Empirical Design							
N observations	Number of obs. in the original regression	582	1206	1270	673	1606	2233
EM-DAT	1 if disasters data from EM-DAT, else 0	582	0.54	0.50	673	0.53	0.50
Climatic disaster	1 if climatic natural disasters included, else 0	582	0.85	0.37	673	0.88	0.33
Geologic disaster	1 if geologic natural disasters included, else 0	582	0.42	0.49	673	0.60	0.49
Other disaster	1 if non-natural disasters included, else 0	582	0.01	0.11	673	0.26	0.44
N years	Period considered in the estimation	582	36	11	673	35	13
1940s	1 if data included disasters in the '40s, else 0	582	0.02	0.12	673	0	0
1950s	1 if data included disasters in the '50s, else 0	582	0.02	0.12	673	0.13	0.34
1960s	1 if data included disasters in the '60s, else 0	582	0.32	0.47	673	0.37	0.48
1970s	1 if data included disasters in the '70s, else 0	582	0.76	0.43	673	0.85	0.36
1980s	1 if data included disasters in the '80s, else 0	582	0.98	0.14	673	0.95	0.23
1990s	1 if data included disasters in the '90s, else 0	582	0.99	0.06	673	1	0
2000s	1 if data included disasters in the '00s, else 0	582	0.98	0.14	673	0.85	0.36
N countries	Number of countries in the sample	547	64	43	636	81.71	49.20
Africa	1 if African countries were included, else 0	394	0.82	0.38	628	0.80	0.40
Asia	1 if Asian countries were included, else 0	394	0.84	0.37	628	0.89	0.32
Europe	1 if European countries were included, else 0	392	0.66	0.47	628	0.71	0.46
LAC	1 if Latin American–Caribbean included	394	0.83	0.38	628	0.92	0.27
North America	1 if North American countries included, else 0	394	0.74	0.44	628	0.77	0.42
Oceania	1 if countries in Oceania were included, else 0	394	0.65	0.48	628	0.75	0.43
Medium-run	1 if consider impact in the med.-run, else 0	582	0.01	0.08	673	0.04	0.19
Long-run	1 if consider impact in the long-run, else 0	582	0.05	0.22	673	0.27	0.45
Estimation technique							
Panel	1 if dataset panel (0=cross-section) , else 0	582	0.93	0.26	673	0.91	0.28
OLS	1 if the estimation with OLS, else 0	582	0.33	0.47	673	0.54	0.50
GMM	1 if the estimation with GMM, else 0	582	0	0	673	0.18	0.38
IV/2SLS	1 if the estimation with IV/2SLS, else 0	582	0.09	0.29	673	0.08	0.27
Neg. Binomial	1 if the estimation with GMM, else 0	582	0.25	0.43	673	0	0
ZINB	1 if the estimation with GMM, else 0	582	0.09	0.28	673	0	0
Country FE	1 if the estimation uses fixed effects, else 0	582	0.33	0.47	673	0.55	0.50
Resilience factors							
Population	1 if indicator of population is included, else 0	582	0.87	0.34	673	0.33	0.47
GDP	1 if indicator of income is included, else 0	582	0.83	0.37	673	0.73	0.45
Education	1 if indicator of education level is included	582	0.02	0.13	673	0.21	0.41
Investment	1 if indicator of investment is included, else 0	582	0.01	0.10	673	0.49	0.50
Openness	1 if indicator of openness is included, else 0	582	0.10	0.30	673	0.62	0.49
Institutions	1 if indicator of institutions is included, else 0	582	0.35	0.48	673	0.30	0.46
Published	1 if the study was published, else 0	582	0.34	0.47	673	0.54	0.49

Source: Authors' elaborations.

Figure 2.6 classifies the t-values that are reported in the 44 primary studies by means of the sign and significance level (Appendix table A1.3 reports the detailed counts). The figure provides the results considering also when the t-values were insignificant. For example for model type (1) studies, I recorded 483 t-values that were reported including an indicator of wealth (as listed in Table A1.3 in the appendix). The t-values are negative and significant in 66% of the cases positive and significant in 20% of the cases and insignificant in the remaining 14% of the cases. A negative result suggests that controlling for GDP/income the average disaster direct cost is more likely to be negative.

Figure 2.6 The effects of resilience factors on disaster impacts by model type.



Source: Appendix Table A1.3

Figure 2.6 allows three observations. First, disagreement varies depending on the cost category (model type) analyzed. Studies on direct costs show a prevalence of negative disaster effects while non-significant disaster effects seems to prevail in indirect costs studies. Second, disagreement varies depending on the resilience factor considered. Direct cost studies show disagreement only in the case of investment where negative and significant t-values reach the same percentage of insignificant t-values. Note that only one study considered investment. Disagreement is more pronounced in indirect costs studies where the share of insignificant results is comparable to the significant negative and positive results, except for primary studies that include education. Interestingly, GDP and institutional quality seem to enlarge the indirect costs of natural disasters. Third, the main conclusion of this section, however, is that there is a need to pay much more attention to the way the model is theoretically and empirically built since authors' decisions about these aspects seem to be crucial in determining the sign and significance of natural disaster impacts.

2.4 Empirical results: The meta equation

To investigate the influence of study characteristics on the sign and level of significance of the t-statistic I use a meta-regression analysis. I follow the approach of Waldorf and Byun (2005) and Koetse et al. (2009) and use an ordered probit model. Waldorf and Byun and Koetse et al. consider negative and positive insignificant results in the same category, here I want to emphasize also the sign of insignificant disaster effects, hence I use four categories: negative and significant, negative non-significant, positive non significant and positive and significant disaster impact for studies on direct and indirect costs separately. For both costs/model types, the underlying latent regression is

$$y_{ij}^{*} = \theta_0 + \theta_1 \boldsymbol{ED}_{ij} + \theta_2 \boldsymbol{ET}_{ij} + \theta_3 \boldsymbol{RF}_{ij} + \varepsilon_{ij} \qquad (2.5)$$

where y_{ij}^{*} is the i estimated effect size drawn from the jth study, $\boldsymbol{ED}$, $\boldsymbol{ET}$ and $\boldsymbol{RF}$ are vectors of empirical design, estimation technique and resilience factors respectively, ε is the normally distributed error term. Estimations were robust to the inclusion or exclusion of the constant θ_0. Rather than y^* I observe the four categories of y

- $y = 1$ if the reported t-value in regression i in study j is negative and significant at least at 10% (lower or equal to -1.65),
- $y = 2$ if it is negative and non significant (between -1.65 and 0),
- $y = 3$ if it is positive and non significant (between 0 and +1.65) and
- $y = 4$ if it is positive and significant at least at 10% (greater or equal to +1.65).

Following the analysis in Section 3 and Bijmolt and Pieters (2001) I apply the following weights to consider that I collected a different number of t-values from every study

$$w_{ij} = M/(M_j J) \quad , \qquad \forall\, j = 1, \dots, J\, , i = 1, \dots, M_j \qquad (6)$$

where M is the total number of t-values, M_j is the number of t-values from study j, and J is the total number of studies for the cost category analyzed. In order to control for within-study dependence of t-values I also cluster standard errors by study. I provide two different specifications. [16] The first is more parsimonious; the second accounts for decades and regional disaggregation in the datasets used by the different studies. Ordered probit marginal effects are presented in Table 2.6 for direct costs studies while results for indirect costs studies are outlined in Table 2.7. Some observations/studies dropped out of the estimated meta-analyses because of missing data on the number of countries and regional disaggregation. Note that although some observations drop in the second specification, both the likelihood ratio and Wald test suggest that the less parsimonious specification fits the data significantly better for both direct and indirect costs studies (p-value: 0.000). Details on the excluded observations/studies are reported in the concluding section.

2.4.1 Direct costs studies (Table 2.6)

The most parsimonious model is presented in specification (A-1) while time dummies and regional disaggregation are included in specification (A-2). Starting with results in (A-1), it seems that when EM-DAT is the underlying disaster database in direct costs studies, there is a 27% higher probability that the disaster has a negative and significant effect. Note that EM-DAT is the only database in the sample that includes also non-natural disasters (the variable "Other"). Accordingly, the only disaster category that seems to significantly increase the probability of finding negative and significant effects is "Other", that is manmade disasters. The estimated marginal effect mimics the EM-DAT one. Regarding estimation techniques, studies using OLS have a higher probability to find non-significant or significantly positive disaster outcome. Given that for direct costs studies the dependent variable is more likely to have a non-normal distribution, this may reflect lower precision in OLS estimates. As to resilience variables, studies that include population size/density have a 11% lower probability to report negative and significant results. This contrasts with the general understanding that areas with more inhabitants are more vulnerable. Finally, publication bias seems to occur towards negative and significant

[16] I also estimated the model with three categories of the outcome variable, the second one including both the positive and negative insignificant t-values. Results are robust. I can provide them upon request.

results (25% higher probability). However, the introduction of time dummies and regional disaggregations (A-2) clarifies that results in the studies on direct costs are driven by disaster databases construction rather than by publication bias. Indeed, the inclusion of regions in the sample, the consideration of long-term disaster effects and the use of instrumental variables estimation technique increases the probability to report a negative and significant result, while the publication bias at the same time becomes insignificant. Note, however, that A2 refers to fewer studies and observations. The Africa dummy suggests that studies including African countries have 65% higher probability to report negative disaster effects. The significantly negative Latin America and Caribbean dummy indicates instead a much lower probability to report a negative result. On the other hand, higher long-run negative results would reflect an increasing trend in the occurrence of major catastrophic natural disasters worldwide. In more recent decades due to increased attention, interests and data availability and reliability, smaller disasters are increasingly included in disaster databases, as reflected by the -40% and -32% probability to report a negative outcome in the meta-regression if disasters in recent decades are considered. Accordingly, the negative long-run effects could be due to the presence of extremely negative events as time goes by. This points to the need to conduct also estimations on subsamples and to account for outliers as, for instance, in Cavallo et al. (2010), Escaleras et al. (2007) and Raschky and Schwindt (2011). Inclusion of time and space variables in the meta-equation also renders population insignificant. Note that only one study on direct costs was explicitly considering investment (Rasmussen, 2004), hence the role of this resilience factor should be more investigated in the future.

Table 2.6 Meta-regression analysis (ordered probit marginal effects), disaster impact effects in terms of direct costs, parsimonious model.

	(A-1)								(A-2)							
Outcome(c)	(1) Significant negative		(2) Insignif. negative		(3) Insignif. positive		(4) Significant positive		(1) Significant negative		(2) Insignif. negative		(3) Insignif. positive		(4) Significant positive	
P(y=c), sd	0.45	(0.21)	0.25	(0.06)	0.18	(0.08)	0.12	(0.13)	0.47	(0.23)	0.24	(0.06)	0.17	(0.08)	0.12	(0.15)
N	0.00	(-0.57)	0.00	(0.55)	0.00	(0.56)	0.00	(0.58)	0.00	(0.21)	0.00	(-0.21)	0.00	(-0.21)	0.00	(-0.21)
EMDAT	0.27***	(3.09)	-0.08**	(-2.47)	-0.12***	(-2.82)	-0.07**	(-2.00)	0.08	(0.41)	-0.03	(-0.41)	-0.04	(-0.41)	-0.01	(-0.42)
Nyears	0.00	(1.21)	0.00	(-1.12)	0.00	(-1.16)	0.00	(-1.18)	0.04	(1.59)	-0.01	(-1.39)	-0.02	(-1.54)	-0.01	(-1.24)
1960s									-0.47	(-1.24)	0.15	(1.15)	0.25	(1.21)	0.07	(1.06)
1970s									-0.21	(-1.03)	0.07	(0.96)	0.11	(1)	0.03	(0.94)
1980s									-0.16	(-0.41)	0.05	(0.42)	0.08	(0.4)	0.02	(0.4)
1990s									-0.40*	(-1.65)	0.13	(1.44)	0.22	(1.59)	0.06	(1.26)
2000s									-0.32**	(-2.03)	0.10*	(1.81)	0.17*	(1.82)	0.05	(1.39)
Ncountries	0.00	(1.59)	0.00	(-1.58)	0.00	(-1.43)	0.00	(-1.45)	0.00	(1.5)	0.00	(-1.33)	0.00	(-1.5)	0.00	(-1.14)
Africa									0.65***	(5.22)	-0.21***	(-2.78)	-0.35***	(-3.48)	-0.10*	(-1.9)
Asia									0.21	(0.65)	-0.07	(-0.61)	-0.11	(-0.67)	-0.03	(-0.61)
Europe									-0.12	(-0.76)	0.04	(0.78)	0.06	(0.74)	0.02	(0.68)
LAC									-0.75***	(-8.47)	0.24***	(2.95)	0.40***	(4.22)	0.11**	(2)
North Am.									-0.17	(-0.85)	0.05	(0.78)	0.09	(0.87)	0.03	(0.76)
Oceania									0.28	(1.21)	-0.09	(-1.23)	-0.15	(-1.15)	-0.04	(-0.96)
Climatic	0.01	(0.14)	0.00	(-0.14)	-0.01	(-0.14)	0.00	(-0.14)	-0.12	(-1.03)	0.04	(0.99)	0.06	(1)	0.02	(0.91)
Geologic	-0.01	(-0.10)	0.00	(0.10)	0.00	(0.10)	0.00	(0.10)	-0.08	(-0.63)	0.03	(0.56)	0.04	(0.66)	0.01	(0.61)
Other	0.86***	(5.83)	-0.26***	(-3.53)	-0.37***	(-3.56)	-0.23***	(-2.69)	-0.27	(-0.59)	0.09	(0.59)	0.14	(0.59)	0.04	(0.56)
Medium2	-0.10	(-1.17)	0.03	(1.07)	0.04	(1.30)	0.03	(0.99)	-0.20	(-1.35)	0.06	(1.11)	0.10	(1.48)	0.03	(1.06)
Long5	0.11	(0.76)	-0.03	(-0.71)	-0.05	(-0.74)	-0.03	(-0.82)	1.33***	(2.94)	-0.43**	(-2.27)	-0.71**	(-2.51)	-0.20	(-1.59)
Panel	-0.10	(-1.6)	0.03*	(1.79)	0.04	(1.45)	0.03	(1.29)	0.46**	(2.02)	-0.15**	(-2.1)	-0.24*	(-1.68)	-0.07	(-1.41)
OLS	-0.27***	(-2.62)	0.08**	(2.31)	0.12**	(2.00)	0.07**	(2.41)	-0.09	(-0.69)	0.03	(0.7)	0.05	(0.67)	0.01	(0.63)
IV	0.19	(1.50)	-0.06	(-1.48)	-0.08	(-1.47)	-0.05	(-1.25)	0.27*	(1.89)	-0.09	(-1.71)	-0.14*	(-1.71)	-0.04	(-1.38)
NegBin	-0.12	(-1.38)	0.04	(1.37)	0.05	(1.26)	0.03	(1.30)	0.10	(1.02)	-0.03	(-1.03)	-0.05	(-0.98)	-0.01	(-0.9)
ZINB	0.08	(0.61)	-0.02	(-0.60)	-0.03	(-0.60)	-0.02	(-0.61)	-0.07	(-0.46)	0.02	(0.46)	0.04	(0.46)	0.01	(0.45)
CountryFE	0.02	(0.25)	-0.01	(-0.24)	-0.01	(-0.24)	0.00	(-0.26)	-0.08	(-0.71)	0.02	(0.67)	0.04	(0.73)	0.01	(0.66)
Population	-0.11*	(-1.78)	0.03*	(1.73)	0.05*	(1.80)	0.03	(1.34)	0.12	(1.06)	-0.04	(-0.95)	-0.07	(-1.09)	-0.02	(-0.89)
GDP	-0.04	(-0.59)	0.01	(0.59)	0.02	(0.58)	0.01	(0.58)	-0.06	(-0.5)	0.02	(0.5)	0.03	(0.51)	0.01	(0.48)
Education	-0.06	(-0.98)	0.02	(0.96)	0.03	(0.98)	0.02	(0.90)	0.19	(1.01)	-0.06	(-0.99)	-0.10	(-0.96)	-0.03	(-0.94)
Investment	-0.13	(-1.62)	0.04	(1.47)	0.05*	(1.65)	0.03	(1.34)	-0.05	(.)	0.02***	(3.12)	0.03***	(5.41)	0.01*	(1.99)
Openness	0.12	(1.54)	-0.04	(-1.42)	-0.05	(-1.60)	-0.03	(-1.25)	-0.24	(-1.23)	0.08	(1.23)	0.13	(1.14)	0.04	(1.07)
Institutions	0.08	(1.32)	-0.02	(-1.19)	-0.03	(-1.30)	-0.02	(-1.27)	0.00	(-0.01)	0.00	(0.01)	0.00	(0.01)	0.00	(0.01)
Published	0.25***	(3.86)	-0.08***	(-2.75)	-0.11***	(-3.11)	-0.07**	(-2.35)	-0.06	(-0.64)	0.02	(0.66)	0.03	(0.61)	0.01	(0.6)
Pseudo R^2								0.205								0.230
N studies								26								24
N obs.								547								373

Source: Autor's elaborations.

Note: Outcomes are 1=negative significant, 2=negative insignificant, 3=positive insignificant, 4= positive significant. Z-values in parenthesis. *, **, *** stands for 10, 5 and 1% level of significance

2.4.2 Indirect costs studies (Table 2.7)

The parsimonious meta-analysis of disaster indirect costs (B-1) mimics the results on indirect costs concerning non-natural disasters while using EM-DAT *per se* does not seem to significantly influence the reported disaster outcome. Panel studies increase by 34% the probability to present negative and significant outcomes, but a medium or long run perspective of the study increases the probability to have positive disaster outcomes. These observations have to be considered in combination because medium/long run studies usually construct the database as a panel with 3/5 years averages, thus emphasizing the negative nature of disasters upon occurrence (yearly panel and short-term perspective). Studies accounting for education levels (reflecting also post-disaster management capacity) have 12% higher probability to report a positive and significant outcome. By contrast, studies including GDP/income levels in the control variables seem to increase negative and significant outcomes. However, when the meta-analysis accounts for decades and regional disaggregations, again resilience factors levels of significance are downsized except for investment. For panel and medium/long term empirical design the same considerations hold, but the inclusion of decade dummies allow different considerations in comparison with direct costs studies. Firstly, all the collected indirect costs studies included data from the 1990s in every specification, so that the variable is omitted from the meta-analysis. Secondly, including the 1970s seems to increase the probability to report positive and significant results while the inclusion of the 1980s increases the probability to report a negative and significant result. Here a deeper analysis on the events occurring during these decades could shed some light. The 1970s were years of state-led development (oil crisis and low economic performances for most developed countries) while the 1980s witnessed the progressive reduction of state intervention and deep sovereign debt crises in disaster exposed and vulnerable developing countries. Interestingly, the inclusion of Latin America and Caribbean accounts for a higher probability to report a negative disaster outcome for indirect costs while the opposite was occurring for direct costs. Finally, controlling for database time and space characteristics publication bias is emphasized, suggesting that published indirect costs studies are more likely to show negative and significant results.

Table 2.7 Meta-regression analysis (ordered probit marginal effects), disaster impact effects in terms of indirect costs, time and regional disaggregation.

	(B-1)								(B-2)							
Outcome(c)	(1)		(2)		(3)		(4)		(1)		(2)		(3)		(4)	
	Significant negative		Insignif. negative		Insignif. positive		Significant positive		Significant negative		Insignif. negative		Insignif. positive		Significant positive	
P(y=c), sd	0.47	(0.26)	0.23	(0.07)	0.17	(0.10)	0.13	(0.15)	0.44	(0.28)	0.23	(0.09)	0.18	(0.11)	0.15	(0.19)
N	0.00***	(3.96)	-0.00*	(-1.69)	-0.00***	(-2.7)	-0.00***	(-3.56)	0.00***	(6.72)	0.00	(0.37)	0.00***	(-3.54)	0.00***	(-6.52)
EMDAT	0.00	(0.04)	0.00	(-0.04)	0.00	(-0.04)	0.00	(-0.04)	-0.07	(-1.31)	0.00	(-0.38)	0.02	(1.31)	0.05	(1.29)
Nyears	0.00	(0.02)	0.00	(-0.02)	0.00	(-0.02)	0.00	(-0.02)	-0.01	(-1.27)	0.00	(-0.34)	0.00	(1.17)	0.01	(1.28)
1960s									0.24	(0.85)	0.00	(0.31)	-0.08	(-0.81)	-0.16	(-0.86)
1970s									-0.35***	(-4.5)	0.00	(-0.36)	0.12***	(3.4)	0.24***	(3.95)
1980s									0.37***	(2.44)	0.00	(0.36)	-0.12**	(-2.25)	-0.25**	(-2.34)
1990s									-		-		-		-	
2000s									0.03	(0.32)	0.00	(0.21)	-0.01	(-0.31)	-0.02	(-0.32)
Ncountries	0.00	(1.06)	0.00	(-0.84)	0.00	(-1.13)	0.00	(-1.01)	0.00	(0.16)	0.00	(0.16)	0.00	(-0.16)	0.00	(-0.16)
Africa									-0.12	(-0.72)	0.00	(-0.35)	0.04	(0.72)	0.08	(0.71)
Asia									-0.23	(-0.88)	0.00	(-0.32)	0.08	(0.84)	0.15	(0.89)
Europe									-0.15	(-1.11)	0.00	(-0.38)	0.05	(1.12)	0.10	(1.1)
LAC									0.50***	(3.94)	0.01	(0.37)	-0.17***	(-3.08)	-0.34***	(-3.73)
North Am.									0.08	(1.38)	0.00	(0.36)	-0.03	(-1.35)	-0.05	(-1.36)
Oceania									0.19	(1.43)	0.00	(0.34)	-0.06	(-1.29)	-0.13	(-1.43)
Climatic	-0.24	(-1.42)	0.01	(0.88)	0.08	(1.44)	0.15	(1.4)	-0.16	(-0.94)	0.00	(-0.4)	0.05	(0.97)	0.11	(0.94)
Geologic	-0.03	(-0.39)	0.00	(0.39)	0.01	(0.39)	0.02	(0.39)	0.11	(1.35)	0.00	(0.39)	-0.04	(-1.36)	-0.07	(-1.33)
Other	0.24***	(2.85)	-0.01	(-1.3)	-0.08**	(-2.38)	-0.14***	(-2.74)	0.06	(0.63)	0.00	(0.3)	-0.02	(-0.61)	-0.04	(-0.63)
Medium2	-0.10*	(-1.8)	0.01	(0.92)	0.03*	(1.66)	0.06*	(1.88)	-0.05*	(-1.75)	0.00	(-0.38)	0.02*	(1.93)	0.03*	(1.65)
Long5	-0.09*	(-1.89)	0.00	(1.1)	0.03	(1.62)	0.05*	(1.98)	-0.11**	(-2.1)	0.00	(-0.36)	0.04**	(1.96)	0.08**	(2.04)
Panel	0.34**	(2.44)	-0.02	(-1.08)	-0.11**	(-2.42)	-0.21**	(-2.33)	0.49**	(2.12)	0.01	(0.36)	-0.16*	(-1.88)	-0.33**	(-2.11)
OLS	0.09	(1.08)	-0.01	(-0.8)	-0.03	(-1.07)	-0.06	(-1.07)	-0.01	(-0.15)	0.00	(-0.15)	0.00	(0.15)	0.01	(0.15)
IV	0.07	(0.86)	0.00	(-0.84)	-0.02	(-0.81)	-0.04	(-0.86)	0.15**	(2.29)	0.00	(0.36)	-0.05**	(-2)	-0.10**	(-2.25)
GMM	-0.03	(-0.31)	0.00	(0.31)	0.01	(0.31)	0.02	(0.31)	0.03	(0.3)	0.00	(0.21)	-0.01	(-0.3)	-0.02	(-0.3)
CountryFE	-0.07	(-1.14)	0.00	(0.93)	0.02	(1.06)	0.05	(1.16)	0.06	(1.63)	0.00	(0.35)	-0.02	(-1.47)	-0.04	(-1.64)
Population	0.04	(0.55)	0.00	(-0.48)	-0.01	(-0.56)	-0.03	(-0.56)	0.01	(0.2)	0.00	(0.2)	0.00	(-0.2)	-0.01	(-0.2)
GDP	0.18***	(3.04)	-0.01	(-1.57)	-0.06**	(-2.48)	-0.11***	(-2.75)	0.08	(1.56)	0.00	(0.36)	-0.03	(-1.43)	-0.05	(-1.59)
Education	-0.20***	(-2.95)	0.01	(1.43)	0.07***	(2.59)	0.12***	(2.64)	0.00	(-0.02)	0.00	(-0.02)	0.00	(0.02)	0.00	(0.02)
Investment	-0.02	(-0.26)	0.00	(0.27)	0.00	(0.26)	0.01	(0.26)	0.10**	(2.27)	0.00	(0.35)	-0.03**	(-1.99)	-0.07**	(-2.23)
Openness	0.09	(1.19)	-0.01	(-1.1)	-0.03	(-1.13)	-0.06	(-1.16)	-0.07	(-1.34)	0.00	(-0.39)	0.02	(1.32)	0.05	(1.34)
Institutions	0.08	(1.21)	0.00	(-1.24)	-0.03	(-1.13)	-0.05	(-1.19)	0.06	(1.02)	0.00	(0.32)	-0.02	(-0.95)	-0.04	(-1.02)
Published	0.10	(1.19)	-0.01	(-0.87)	-0.03	(-1.31)	-0.06	(-1.12)	0.20**	(2.16)	0.00	(0.37)	-0.07**	(-2.12)	-0.14**	(-2.07)
Pseudo R^2								0.158								0.186
N studies								19								18
N obs.								636								591

Source: Autor's elaborations.

Note: Outcomes are 1=negative significant, 2=negative insignificant, 3=positive insignificant, 4= positive significant. Z-values in parenthesis. *, **, *** stands for 10, 5 and 1% level of significance.

2.5 Conclusions

The debate on the impact of natural disasters and the possible mitigation strategies has become lively during the last decade due to an increase in the occurrence of natural hazards. This study attempts to re-organize the recent macroeconomic empirical literature and investigates whether the relationship between the likelihood of a disaster to generate (in)significant negative or (in)significant positive effects is influenced by the empirical design (source of data and time and regional characteristics of the samples), estimation techniques, resilience factors considered in the analysis and publication bias. Many argue for different climatic and geologic disasters impacts, but this is not reflected by the meta-analysis. The meta-analysis emphasizes the importance of time and regional characteristics of the disaster dataset subsamples used in the primary studies, especially in the analysis of disaster direct costs. Publication bias seems to occur in studies on disaster indirect costs, biasing the literature towards reporting negative and significant disaster outcomes.

It is important to note that some studies were excluded from the meta-analysis due to missing number of observations in the regression results tables (Benson and Clay, 1998; Jaramillo, 2009; Simmons and Sutter, 2005). Some observations/studies cannot be included in the meta-analysis due to lacking information on the countries included in primary studies regression sub-samples.[17] In Table 2.8 I report details on the excluded observations/studies for every specification in Table 2.6 and 2.7. Table 2.8 has two objectives. First, it is meant to further support the results, showing that the excluded observations/studies were showing results in line with the general findings of the meta-analyses. Second, Table 2.8 emphasizes the need to clarify the characteristics of the subsamples used across the whole regression estimations in order to make explicit the underlying data, increase the generalizability of the results and allow replication of the results presented.

[17] In some cases I was able to infer the missing information, otherwise I contacted authors of the primary studies but not all of them were able to provide the necessary detailed data.

Table 2.8 Details on observations excluded from the meta-analyses.

	Specification 1: obs/study excluded due to missing number of countries in primary study regression results				Specification 2: obs/study excluded due to missing number/list of countries in the primary study regression results				Conclusion supported [a]
	Primary study	Dropped obs.	Study drops?	Publish.	Primary study	Dropped obs.	Study drops?	Publish.	
Direct Costs Table 2.6 (A) N=582	Cavallo et al. (2010)	19	Yes	Yes	Cavallo et al. (2010)	19	Yes	Yes	Higher losses for developing countries
	Bakkensen (2013)	8	No	No	Bakkensen (2013)	153	Yes	No	Higher losses for developing countries
	Ahmed and Iqbal (2009)	8	No	No	Ahmed and Iqbal (2009)	26	No	No	Higher damages for developed countries, no difference between climatic and geologic disasters
					Yamamura (2011a)	8	Yes	No	Higher losses for developing countries
					Yamamura (2011b)	2	No	No	Higher losses for developing countries
					Patt et al. (2010)	1	No	Yes	Higher losses for developing countries
Indirect costs Table 2.7 (B) N=673	Felbermayr and Groschl (2013a)	32	No	No	Felbermayr and Groschl (2013a)	32	No	No	Poor countries more affected by geological disasters, rich countries more affected by meteorological disasters
	Felbermayr and Groschl (2013b)	3	No	Yes	Felbermayr and Groschl (2013b)	3	No	Yes	Higher losses for developing countries
	Noy (2009)	2	No	Yes	Noy (2009)	2	No	Yes	Higher losses for developing countries
					Tavares (2004)	45	Yes	Yes	Negative effects of natural disasters

Source: Author's elaborations.

Note: [a] The term losses stands either for losses in terms of deaths, affected or economic damages.

To conclude, adding to the IPCC literature review on the macroeconomic effects of natural disasters, the meta-analysis I elaborated is able to show *higher confidence* for the negative effects of natural disasters in terms of both direct and indirect costs. Future studies should pay more attention to the regional and countries aggregations used for the estimations of the macroeconomic impacts of natural disasters, consider outliers analysis (as suggested in section 2.3.1), give more attention to certain resilience factors (investment, education and openness for direct cost studies, and education and institutions in indirect costs studies), while peer-reviewing should moderate the preference for reported sensational disaster negative effects.

References

Ahmed, M. and K. Iqbal (2009) 'Disaster and decentralization', Carleton College Department of Economics Working Paper Series No. 2009-03. Northfield, MN: Department of Economics, Carleton College.

Albala-Bertrand, J.M. (1993a) *Political economy of large natural disasters with special reference to developing countries*. Oxford: Calendron Press.

Albala-Bertrand, J.M. (1993b) 'Natural Disaster Situations and Growth: A Macroeconomic Model for Sudden Disaster Impacts', *World Development* 21 (9): 1417–1434.

Anbarci, N., M. Escaleras, and C. A. Register (2005) 'Earthquake Fatalities: The Interaction of Nature and Political Economy.' *Journal of Public Economics* 89 (x): 1907–1933.

Bakkensen, L.A. (2013) 'Natural disasters and adaptation: evidence from global tropical cyclone damages', Job market paper, Yale University. Accessed 15 December 2013, available at http://cbey.yale.edu/uploads/Environmental%20Economics%20Seminar/Bakkensen_Cyclones.pdf.

Benson, C. and E. Clay (1998) 'The Impact of Drought on Sub-Saharan African Economies: A Preliminary Examination', *World Bank Technical Paper Series* No. 401. Washington, DC: World Bank.

Benson, C. and E. J. Clay (2004) 'Understanding the Economic and Financial Impacts of Natural Disasters.' *Disaster Risk Management Series* 4. Washington DC: World Bank.

Bergholt, D. and P. Lujala (2012) 'Climate-related natural disasters, economic growth, and armed civil conflict', *Journal of Peace Research* 49 (1): 147-162.

Bijmolt, T.H.A. and R.G.M. Pieters (2001) 'Meta-analysis in marketing when studies contain multiple measurements', *Marketing Letters* 12 (2): 157-69.

Cavallo, E., S. Galiani, I. Noy and J. Pantano (2013) 'Catastrophic natural disasters and economic growth', *The Review of Economics and Statistics* 95 (5): 1549-1561.

Cavallo, E. and I. Noy Y (2010) 'The Economics of Natural Disasters. A Survey.', *IDB Working Paper Series 124*. Washington: Inter-American Development Bank.

Cavallo, E. A. Powell and O. Becerra (2010) 'Estimating the direct economic damages of the earthquake in Haiti', *The Economic Journal* 120 (August): F298-F312.

Cuaresma, J.C., J. Hlouskova and M. Obersteiner (2008) 'Natural disasters as creative destruction? Evidence from developing countries', *Economic Enquiry* 46 (2): 214-226.

Czajkowski, J. and E. Kennedy (2010) 'Fatal tradeoff? Toward a better understanding of the costs of not evacuating from a hurricane in landfall counties', *Population and Environment* 31 (1–3): 121–149.

Czajkowski, J., K. Simmons and D. Sutter (2011) 'An Analysis of Coastal and Inland Fatalities in Landfalling US Hurricanes', *Natural Hazards* 59 (3): 1513-1531.

Davis, L. (1992) *Natural Disasters: From the Black Plague to the Eruption of Mt. Pinatubo*. New York: Facts on File.

Dercon, S. (2004) 'Growth and Shocks: Evidence from Rural Ethiopia', *Journal of Development Economics* 74(2): 309–329.

Dercon, S. and P. Krishnan (2000) 'In Sickness and in Health: Risk Sharing within Households in Rural Ethiopia', *Journal of Political Economy* 108 (4): 688–727.

Diebel, D. and R. Wooster (2010) 'Productivity Spillovers from Foreign Direct Investments in Developing Countries: A Meta-regression Analysis.', *Review of Development Economics* 14 (3): 640–655.

Djankov, S. and P. Murrel (2002) 'Enterprise Restructuring in Transition: A Quantitative Survey', *Journal of Economic Literature* 40(3): 739–792.

Doucouliagos, H. and M. Paldam (2011) 'The ineffectiveness of development aid on growth: An update', *European Journal of Political Economy* 27: 399–404.

EM-DAT (2011) The International Disaster Database. Louvain, Belgium: Centre for Research on the Epidemiology of Disasters.

Escaleras, M., N. Anbarci and C.A. Register (2007) 'Public Sector Corruption and Major Earthquakes: A Potentially Deadly Interaction', *Public Choice* 132: 209–230.

Escaleras, M. and C.A. Register (2012) 'Fiscal Decentralization and Natural Hazards', *Public Choice* 151: 165-183.

Felbermayr, G. and J. Groschl (2013a) 'Naturally negative: the growth effects of natural disasters', *CESifo Working Paper* No. 4439. Munich, Germany: Ludwig-Maximilians University Center for Economic Studies and Ifo Institute.

Felbermayr, G. and J. Groschl (2013b) 'Natural disasters and the effect of trade on income: a new panel IV approach', *European Economic Review* 58 (February): 18-30.

Ferreira, S., K. Hamilton and J.R. Vincent (2011) 'Nature, socioeconomics and adaptation to natural disasters', *World Bank Policy Research Working Paper* 5725. Washington, DC: World Bank.

Fomby, T., Y. Ikeda and N.V. Loayza (2013) 'The growth aftermath of natural disasters', *Journal of Applied Econometrics* 28: 412-434

Gaiha, R., K. Hill, G. Thapa and V.S. Kulkarni (2013) 'Have natural disasters become deadlier?', *BWPI Working Paper* 181. Manchester, UK: The University of Manchester, Brooks World Poverty Institute.

Ghimire, R. and S. Ferreira (2013) 'Economic shocks and civil conflict', paper presented at the Southern Agricultural Economics Association (SAEA) Annual Meeting (3-5 February 2013). Accessed 15 December 2013, available at http://ageconsearch.umn.edu/bitstream/142587/2/ghimire%20and%20ferreira_013.pdf.

Hallegatte, S. (2012) 'A cost effective solution to reduce disaster losses in developing countries. Hydro-meteorological services, early warning, and evacuation', *World Bank Policy Research Working Paper* 6058. Washington, DC: World Bank.

Hallegatte, S. and P. Dumas (2009) 'Can natural disasters have

Hallegatte, S. and V. Przyluski (2010) 'The Economics of Natural Disasters. Concepts and Methods.' *World Bank Policy Research Working Paper 5507*. Washington DC: World Bank.

Havránek and Iršová (2010) 'Meta-Analysis of Intra-Industry FDI spillovers: Updated Evidence', *Czech Journal of Economics and Finance* 60, pp. 151–174.

Heger, M., A. Julca, and O. Paddison (2008) 'Analyzing the Impact of Natural Hazards in Small Economies: The Caribbean Case.' *UNU/WIDER Research Paper2008/25*. UNU/WIDER Helsinki

Higgins, J.P.T. and S. Green (eds) (last update 2011) *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0. The Cochrane Collaboration. Accessed January 2014, available at www.cochrane-handbook.org.

IPCC (Intergovernmental Panel on Climate Change) (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. (The SREX Report). Cambridge and New York: Cambridge University Press. Available at: <http://ipcc-wg2.gov/SREX/report/> Accessed 20 May 2013.

Jackson, O. (2013) 'Natural disasters, foreign aid, and economic growth'. Accessed 15 December 2013, available at SSRN: http://ssrn.com/abstract=2329404 or http://dx.doi.org/10.2139/ssrn.2329404

Jaramillo, C. R. H. (2009) *Do Natural Disasters Have Long-Term Effects On Growth?* Manuscript. Bogotá, Colombia: Universidad de los Andes.

Kahn, M E. (2005) 'The Death Toll from Natural Disasters: The Role of Income, Geography, and Institutions', *Review of Economics and Statistics* 87(2): 271–284.

Kazianga, H. and C. Udry (2006) 'Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso', *Journal of Development Economics* 79 (2006) 413–446.

Keefer, P., E. Neumayer and T. Plümper (2011) 'Earthquake Propensity and the Politics of Mortality Prevention', *World Development* 39 (9): 1530-1541.

Kellenberg, D. K., and A. M. Mobarak (2008) 'Does Rising Income Increase or Decrease Damage Risk from Natural Disasters?', *Journal of Urban Economics* 63(3): 788–802.

Kim, C. (2010) 'The Effects of Natural Disasters on Long-Run Economic Growth.', *The Michigan Journal of Business* 41: 15–49.

Koetse, M.J., H.L.F. de Groot and R.J.G.M. Florax (2009) 'A meta-analysis of the investment-uncertainty relationship', *Southern Economic Journal* 76 (1): 283-306.

Loayza, N., E. Olaberria, J. Rigolini and L. Christiaensen (2012) 'Natural Disasters and Growth: Going Beyond the Averages', *World Development* 40 (7): 1317–1336.

Maccini, S.L. and D. Yang (2008) 'Under the Weather: Health, Schooling, and Economic Consequences of Early-Life Rainfall', *NBER Working Paper 14031*. Cambridge, MA: NBER.

Mebratie, A.D., and P.A.G. van Bergeijk (2013) 'Firm heterogeneity and development: a meta analysis of FDI productivity spillovers," *Journal of International Trade and Economic Development*, in print.

Moons, S. and P.A.G. van Bergeijk (2012) 'Does Economic Diplomacy Work? A Meta Analysis on the Effect of Economic Diplomacy on International Economic Flows', paper presented at the IADB conference 'The Effects of Trade and Investment Promotion', 11-12 October 2012.

Moreno, A. and O.D. Cardona (2011) 'Efectos de los desastres naturales sobre el crecimiento, el desempleo, la inflación y la distribución del ingreso: Una evaluación de los casos de Colombia y México', background paper prepared for the *2011 Global Assessment Report on Disaster Risk Reduction*. Geneva, Switzerland: United Nations International Strategy for Disaster Reduction.

Murlidharan, T.L. and H.C. Shah (2003) 'Economic Consiqences of Catastrophes Triggered by Natural Hazards', *Report* 143. Stanford, CA, USA: Department of Civil and Environmental Engineering, Stanford University.

Neumayer, E., T. Plümper and F. Barthel (2013) 'The Political Economy of Natural Disaster Damage', *Global Environmental Change* (forthcoming).

Nordhaus, W. (2010) 'The economics of hurricanes and implications of global warming', *Climate Change Economics* 1 (1): 1–20.

Noy, I. (2009) 'The Macroeconomic Consequences of Disasters.', *Journal of Development Economics* 88(2): 221–231.

Noy, I. and A. Noualsri (2007) 'What do Exogenous Shocks tell us about Growth Theories?', University of Hawaii Working Paper 07-28.

Noy, I. and T.B. Vu (2010) 'The economics of natural disasters in a developing country: The case of Vietnam', *Journal of Asian Economics*, 21 (4): 345-354.

Okuyama, Y. (2003) 'Economics of natural disasters: A critical review', *Research paper* 2003-12, paper presented at the 50th North American Meeting, Regional Science Association International (November 20-22) in Philadelphia, PA.

Okuyama, Y. (2007) 'Economic Modeling for Disaster Impact Analysis: Past, Present and Future.', *Economic Systems Research* 19 (2): 115–124.

Padli, J. and M.S. Habibullah (2009) 'Natural Disaster Death and Socio-Economic Factors in Selected Asian Countries: A Panel Analysis', *Asian Social Science* 5 (4): 65–71.

Patt, A.G., M. Tadross, P. Nussbaumer, K. Asante, M. Metzger, J. Rafael, A. Goujon, and G. Brundrit (2010) 'Estimating least-developed countries' vulnerability to climate- related extreme events over the next 50 years', *Proceedings of the National Academy of Sciences*, 107 (4): 1333-1337.

Pelling, M., Ozerdem, A. and S. Barakat (2002) 'The Macro-economic Impact of Disasters', *Progress in Development Studies* 2 (4): 283–305.

Raddatz C. (2007) 'Are External Shocks Responsible for the Instability of Output in Low-Income Countries?', *Journal of Development Economics* 84(1): 155–187.

Rappaport, E. (2000) 'Loss of life in the United States associated with recent Atlantic tropical cyclones', *Bulletin of the American Meteorological Society* 81 (9): 2065–2073.

Raschky, P. A. (2008) 'Institutions and the Losses from Natural Disasters.', *Natural Hazards Earth Systems Science* 8: 627–634.

Raschky, P. and M. Schwindt (2009) 'Aid, Natural Disasters and the Samaritan's Dilemma', *World Bank Policy Research Working Paper* 4952. Washington, DC: World Bank.

Raschky, P. and M. Schwindt (2011) 'Aid, Catastrophes and the Samaritan's Dilemma', *Monash university working paper*. Clayton, Australia: Monash University.

Rasmussen, T. N. (2004) 'Macroeconomic Implications of Natural Disasters in the Caribbean.', *IMF Working Paper WP/04/224*. IMF: Washington DC.

Reed, W.R. and R. Mercer (2013) 'REPLICATION STUDY: Toya and Skidmore (Economics Letters, 2007)', *Working Papers in Economics* 13/05. Christchurch, New Zealand: Department of Economics and finance, University of Canterbury.

Sadowski, N.C. and D. Sutter (2005) 'Hurricane fatalities and hurricane damages: are safer hurricanes more damaging', *Southern Economic Journal* 72 (2): 422-432.

Schumacher, I. and E. Strobl (2011) 'Economic Development and Losses Due to Natural Disasters: The Role of Hazard Exposure', *Ecological Economics* 72 (December): 97-105.

Simmons, K.M. and D. Sutter (2005) 'WSR-88D Radar, Tornado Warnings, and Tornado Casualties', *Weather and Forecasting* 20: 301-310.

Simmons, K.M. and D. Sutter (2009) 'False Alarms, Tornado Warnings, and Tornado Casualties', *Weather, Climate, and Society* 1: 38-53.

Sinani, E. and K. Meyer (2009) 'When and Where does Foreign Direct Investment Generate Positive Spill-overs? A Meta-Analysis', *Journal of International Business Studies* 40 (7): 1075–1094.

Skidmore, M. and H. Toya (2002) 'Do Natural Disasters Promote Long-run Growth?', *Economic Inquiry* 40(4): 664–687.

Skidmore, M. and H. Toya (2013) 'Natural Disaster Impacts and Fiscal Decentralization', *Land Economics* 89 (1): 101–117.

Stanley, T.D. and H. Docouliagos (2012) Meta-regression analysis in economics and business. New York: Routledge.

Strobl, E. (2011) 'The Economic Growth Impact of Hurricanes: Evidence from U.S. Coastal Counties', *The Review of Economics and Statistics* 93 (2): 575–589.

Strobl, E. (2012) 'The Economic Growth Impact of Natural Disasters in Developing Countries: Evidence from Hurricane Strikes in the Central American and Caribbean Regions', *Journal of Development Economics* 97: 130-141.

Tavares, J. (2004) 'The Open Society Assesses its Enemies: Shocks, Disasters and Terrorist Attacks.', *Journal of Monetary Economics* 51: 1039–1070.

Toya, H. and M. Skidmore (2007) 'Economic development and the impacts of natural disasters.', *Economic Letters* 94: 20–25.

Toya, H. and M. Skidmore (2013) 'Reply to "Replication of 'Economic development and the impacts of natural disasters' (Economics Letters, 2007)', *Public Finance Review* 25 (November): 1-6.

UNDP (2004) *Reducing Disaster Risk: A Challenge for Development. A Global Report.* New York: UNDP. Also available at <http://www.preventionweb.net/files/1096_rdrenglish.pdf>.

Von Peter, G., S. von Dahlen and S. Saxena (2012) 'Unmitigated Disasters? New Evidence on the Macroeconomic Cost of Natural Catastrophes', *BIS Working Papers* 394. Switzerland: Bank for International Settlements.

Vos, R., M. Velasco, and E. de Labastida (1999) 'Economic and Social Effects of El Niño in Ecuador, 1997-1998.', Inter-American Development Bank Technical Paper POV-107. IADB: Washington DC

Vu, T.B. and D. Hammes (2010) 'Dustbowls and High Water, the Economic Impact of Natural Disasters in China.', *Asia-Pacific Journal of Social Sciences* 1 (December): 122–132.

Waldorf, B. and B. Byun (2005) 'Meta-analysis of the impact of age structure on fertility', *Journal of Population Economics* 18: 15-40.

Wooldridge, J.M. (2009) *Introductory Econometrics: A Modern Approach.* Mason, OH [etc.]: South-Western/Cengage Learning.

Yamamura, E. (2011a) 'Death caused by natural disasters: the role of ethnic heterogeneity', *EERI Research Paper Series* No. 10/2011. Brussels, Belgium: Economics and Econometrics Research Institute.

Yamamura, E. (2011b) 'Institution, economic development, and impact of natural disasters', *MPRA Paper* No. 32069. Munich, Germany: Munich Personal RePec Archive, available at http://mpra.ub.uni-muenchen.de/32069/.

Yang, D. (2008) 'Coping with disaster: the impact of hurricanes on international financial flows, 1970-2002', *The B.E. Journal of Economic Analysis & Policy* 8 (1 – Advances): Art. 13.

Zapata-Marti, (1997) 'Methodological approaches: the ECLAC methodology.', in Center for the Research on the Epidemiology of Disasters (CRED), *Assessment of the economic impact of natural and man-made* disasters: 10-12. Proceedings of the expert consultation on methodologies, Brussels, 29–30 September. Belgium: Université Catholique de Louvain.

Appendix A1

Appendix Table A1.1 Studies on disaster direct costs used in the meta-analysis and summary statistics for reported t-values.

			Collected t-statistics							Model	Pub.
Study	Dependent Var.	Disaster Var.	Nmax	N	Mean	St.dev	Min	Max	Median	type	
Rasmussen (2004)	Affected, damages	Count	149	12	-2.06	2.64	-6.88	1.41	-2.31	1	0
Anbarci et al. (2005)	Deaths	Count, intensity	269	12	-1.18	2.61	-3.78	6.00	-1.90	1	1
Kahn (2005)	Deaths	Count	1438	12	-3.98	2.81	-9.24	-0.89	-3.14	1	1
Sadowski and Sutter (2005)	Deaths, damages	Intensity, deaths	94	9	-7.44	13.13	-42.39	-2.15	-3.64	1	1
Escaleras et al. (2007)	Deaths	Count, intensity	344	8	-1.70	4.51	-8.29	3.15	-0.90	1	1
Kellenberg and Mobarak (2008)	Deaths	Count	3271	30	-16.78	6.13	-30.46	-6.68	-17.36	1	1
Raschky (2008)	Deaths, damages	Affected	2792	6	-14.70	2.29	-16.83	-12.29	-14.78	1	1
Yang (2008)	Deaths, affected, damages	Intensity	2275	7	-2.29	1.08	-3.79	-0.21	-2.24	1	1
Ahmed and Iqbal (2009) [a]	Deaths, affected	Count	553	43	-8.50	4.22	-24.64	-2.06	-8.04	1	0
Raschky and Schwindt (2009)	Deaths	Dummy	2186	57	-3.50	2.52	-9.44	0.83	-2.89	1	0
Cavallo et al. (2010)	Damages	Count, deaths	1774	19	-13.29	8.29	-21.08	2.34	-17.26	1	1
Czajkowski and Kennedy (2010) [a]	Deaths	Dummy, intensity	511	30	-3.02	1.38	-5.54	-0.48	-3.14	1	1
Patt et al. (2010)	Deaths, affected	Count	154	12	-6.77	2.83	-10.31	-1.81	-7.58	1	1
Czajkowski et al. (2011)	Deaths	Intensity	9326	6	-3.98	2.99	-6.8	0.57	-4.85	1	1
Ferreira et al. (2011)	Deaths	Affected, intensity	2194	25	-3.46	3.71	-14.95	1.01	-3.78	1	1
Keefer et al. (2011)	Deaths	Intensity	1288	10	-2.31	0.50	-2.80	-1.18	-2.30	1	1
Raschky and Schwindt (2011)	Deaths	Affected	2842	52	-11.91	2.10	-15.17	-1.00	-12.29	1	0
Schumacher and Strobl (2011)	Damages	Intensity	93	2	-13.25	15.74	-24.38	-2.12	-13.25	1	1
Yamamura (2011a)	Deaths	Count	3354	8	-2.33	0.27	-2.63	-1.86	-2.37	1	0
Yamamura (2011b)	Deaths	Count	1931	6	-2.62	1.00	-3.62	-0.93	-2.86	1	0
Escaleras and Register (2012)	Deaths, affected	Count	566	9	-3.23	1.74	-6.15	-1.59	-2.55	1	1
Bakkensen (2013)	Deaths, damages	Count	1020	153	1.91	3.41	-8.15	10.71	2.08	1	0
Cavallo et al. (2013)	Deaths, damages	Intensity	428	4	-5.45	2.11	-8.42	-3.91	4.73	1	1
Felbermayr and Groschl (2013a) [b]	Deaths, affected, damages	Intensity	1332	6	-2.81	3.18	-6.36	0.00	-2.08	1	0
Gaiha et al. (2013)	Deaths	Deaths	86	1	3.02	-	3.02	3.02	3.02	1	0
Jackson (2013) [b]	Deaths, affected, damages	Count, intensity	3401	12	-0.71	1.17	-2.6	0.92	-0.87	1	0
Neumayer et al. (2013)	Damages	Intensity	1662	15	-8.47	3.81	-15.43	-2.15	-8.78	1	1

Source: Authors' elaborations.

Note: See Appendix Table A1.2.

Appendix Table A1.2 Studies on disaster indirect costs used in the meta-analysis and summary statistics for reported t-values.

Study	Dependent Var.	Disaster Var.	Collected t-statistics							Model type	Pub.
			Nmax	N	Mean	St.dev	Min	Max	Median		
Skidmore and Toya (2002)	GDP	Count	89	44	0.80	2.32	-3.09	3.91	1.65	2	1
Murlidharan and Shah (2003)	GDP	Affected, damages	151	4	-0.99	4.57	-5.14	3.05	-0.93	2	0
Tavares (2004)	GDP	Count	2418	45	-2.02	0.22	-2.24	-1.38	-2.13	2	1
Noy and Noualsri (2007)	GDP	Deaths, damage	476	46	-0.75	1.14	-2.44	1.50	-0.83	2	0
Heger et al. (2008)	GDP	Dummy, count, deaths, affected, damage	363	11	-1.22	1.51	-3.65	1.02	-1.57	2	0
Noy (2009) [a]	GDP	Dummy, damages, intensity	1574	47	-2.81	2.95	-11.04	2.54	-2.37	2	1
Kim (2010)	GDP	Count	88	15	1.49	1.32	-1.32	2.97	2.06	2	1
Noy and Vu (2010) [a]	GDP	Deaths, affected, damages	546	11	-	-	-	-	-		1
Vu and Hammes (2010) [a]	GDP	Deaths, affected, damages	390	17	-	-	-	-	-	2	1
Strobl (2011)	GDP	Damage	14724	10	-1.93	1.94	-4.65	1.70	-2.52	2	1
Strobl (2012)	GDP	Intensity	969	50	-4.94	20.35	-145.2	1.00	-1.96	2	1
Bergholt and Lujala (2012)	GDP	Affected	4210	15	-4.36	1.72	-6.75	-1.91	-4.27	2	1
Loayza et al. (2012)	GDP	Count	545	40	0.00	2.38	-4.05	5.53	-0.26	2	1
Von Peter et al. (2012)	GDP	Deaths, damages	8252	42	-3.00	2.79	-14.76	2.32	-3.13	2	0
Felbermayr and Groschl (2013a) [b]	GDP	Count, intensity	3099	174	-1.46	2.03	-7.70	3.80	-1.24	2	0
Felbermayr and Groschl (2013b)	GDP	Count	1312	39	-0.20	1.81	-4.11	3.67	0.00	2	1
Fomby et al. (2013)	GDP	Intensity	2097	32	-0.24	1.43	-4.02	1.59	0.10	2	1
Ghimire and Ferreira (2013)	GDP	Count, intensity	2576	4	-1.97	0.31	-2.27	-1.61	-2.00	2	0
Jackson (2013) [b]	GDP	Count, intensity	2853	26	-0.02	1.41	-2.08	3.25	-0.14	2	0
Model (1)				566	-4.40	6.79	-42.39	10.71	-2.83		
Model (2) [a]				644	-1.48	6.14	-145.2	5.53	-1.30		
Full Sample				1210	-2.85	6.61	-145.2	10.71	-1.97		

Source: Authors' elaborations.

Note: Descriptive statistics for the studies on direct costs (Model type 1) are calculated changing the sign of the t-statistics reported in the original study to allow the same interpretation of the effects of disasters across model types. For example, if in the original study on direct costs a disaster indicator had positive t-value, it indicated an increase of disaster direct cost, that is a negative impact of the disaster, hence in the dataset I recorded that t-value with a negative sign. [a] Noy and Vu (2010) and Vu and Hammes (2010) report only p-values or indicators of level of significance while some t-values/standard errors in Ahmed and Iqbal (2009), Czajkowski and Kennedy (2010) and Noy (2009) were missing, so that for 69 coefficients I do not report the related t-value aggregate statistics. [b] Felbermayr and Groschl (2013) analyze both direct and indirect costs.

Appendix Table A1.3 The effects of resilience factors on disaster impacts by model type.

Variable	Negative and significant		Negative and non significant		Positive and non significant		Positive and significant		Total	% full sample	Model type
GDP	317	66%	30	6%	38	8%	98	20%	483	83%	1
Education	8	80%	2	20%	0	0%	0	0%	10	2%	1
Investment	3	50%	1	17%	2	33%	0	0%	6	1%	1
Openness	51	88%	3	5%	4	7%	0	0%	58	10%	1
Population	337	67%	42	8%	29	6%	98	19%	506	87%	1
Institutions	117	87%	15	7%	9	5%	2	1%	203	35%	1
GDP	251	52%	122	25%	70	14%	45	9%	488	73%	2
Education	33	23%	53	37%	26	18%	32	22%	144	21%	2
Investment	141	42%	92	28%	69	21%	31	9%	333	49%	2
Openness	158	38%	121	29%	93	23%	42	10%	414	62%	2
Population	92	41%	68	30%	51	23%	14	6%	225	33%	2
Institutions	104	52%	53	27%	34	17%	8	4%	199	30%	2

Source: Author's elaborations based on the 44 selected studies.

Appendix A2

In the initial phases of every primary research[18] authors usually conduct a review of the existing literature to identify and locate the research question to be investigated in the field of interest. However as there are different types of research questions and different types of search strategies, different types of literature reviews can be undertaken involving different sets of studies (Gough and Elbourne, 2002).[19] Making explicit the methodology used to: conduct the review enhances the rigor of the analysis and allows the final users to understand the process of reaching the results of the review through inclusion/exclusion of studies from the information set; evaluate its comprehensiveness and representativeness, reliability and validity; and replicate, extend and/or update the review presented (Jackson, 1980). These are the standards required to primary studies and should be met by literature reviews and meta analyses in order to increase the transparency of the overall process of research. For "each review is the result of implicit methods, consciously or unconsciously selected by the reviewer" (Jackson, 1980: 440), the definition of the review method can only increase the value added of the literature review and, if that is the case, the value of the connected primary studies. Gough (2007) outlined the 'stages of a review', I use his framework to illustrate the procedure underlying the elaboration of the meta-analysis.

Appendix Table A2.1 Stages of a review.

1) Systematic map of research activity	i. Form review team ii. Formulate review question and develop protocol iii. Define studies to be considered (*inclusion criteria*) iv. Search for studies (*search strategy*) v. Screen studies (*check that meet inclusion criteria*) vi. Describe studies (*systematic map of research*)
2) Systematic synthesis of research evidence	*All the stages of a map plus:* vii. Appraise study quality and relevance [a] viii. Synthesize findings (*answering review question*) ix. Communicate and engage

Source: Author's elaborations from Gough (2007) Figure 2, and Gough (2013).

Note: [a] The stage of quality and relevance assessment can also occur during other stages of the review. Quality can be considered an inclusion/exclusion criteria and therefore occur during stage iii, it can be used as a narrowing criteria in a two stages review (vi) or to conduct sensitivity analysis in the stage of synthesizing findings (viii) (Gough, 2007).

The initial set of studies was 22 (cut-off date being July 2012) and the chapter was explicitly emphasizing the fact that some studies issued in the period considered were not

[18] Here with the term primary research I refer to original published studies independent of the primary or secondary nature of the data collected or analyzed in the study considered.

[19] Oliver et al. (1999) found that six literature reviews on the topic of older people and accident prevention had in common only two out of a total of 137 studies.

included in the sample. The main causes of the scarce initial comprehensiveness were:

- language in which the paper was written
- failure to meet keywords combinations in the phase of literature research
- absence of keywords in the study and without a keywords list
- path dependence in the use of browsers such as Google Scholar: different computers may result in different lists of studies
- temporary unavailability of the server where research papers are stored (for example some World Bank policy working papers cannot easily be found with a general search).

Hence, I further considered in the inclusion criteria the language of the study, carried out multiple searches using different combinations of the selected keywords and using Boolean operators (such as AND, OR, NOT) or selecting the option "incognito mode" when searching articles through Google Scholar. Moreover, I carefully checked cross-referencing in the already collected primary studies and screened studies and reports. The final sample has 44 studies (cut-off date being now December 2013). Appendix Table A2.2 reports a schematic representation of the review conducted in the elaboration of Chapter 2.

Appendix Table A2.2 Stages of the systematic review in Chapter 2.

Stages of a review	Meta analysis
I Systematic map of research activity	
Form review team	Sara Lazzaroni
Formulate review question and develop protocol	• Research question: The macroeconomic impact of natural disasters and its relationship to development • Review methodology: quantitative meta-analysis • Specific protocol: collect t-values from screened studies and meta-equation
Define studies to be considered (inclusion criteria)	• Studies written in English • Macroeconomic studies • Studies using econometric models to quantify the impact of disasters • Studies using as depended variable a disaster direct cost indicator (number of people affected/killed or economic damages) or GDP growth/level (as disaster indirect cost indicator) • Studies including a disaster variable within the explanatory variables • Cut-off point: December 2013
Search for studies (search strategy)	• Repeated searches in time • Internet-based search of studies using Econlit and Google Scholar with these keywords: 'natural disasters', 'impact', 'growth', 'economic development', 'development', 'killed', 'affected', 'institutions', 'econometric' • Use Boolean operators (AND, OR, NOT, *) • "Incognito mode" in path-dependent browsers such as Google Scholar • Cross reference in the collected articles and major reports on the effects of natural disasters (e.g. IPCC, 2012; UNDP, 2004)

(CONTINUE)

(CONTINUE)	
Screen studies (check that meet inclusion criteria)	• Non-English studies were excluded • Some studies were excluded because not reporting the needed t-statistics for the variables considered in the meta-analysis. The studies excluded were: - Literature reviews - Input-output analyses - Computable General Equilibrium Analyses - Microeconometric studies
Describe studies (systematic map of research)	• Studies analyzing direct costs of disasters • Studies analyzing indirect costs of disasters (effects on GDP) • Discussion of the relevant study characteristics in Section 2.1 and 2.2.
II Systematic synthesis of research evidence	
Appraise study quality and relevance	• Exclusion of - Studies using vector autoregression analyses reporting only impulse response functions and not the short- and long-term coefficients - Studies not reporting the number of observations in the regression results. • Some primary studies were not reporting the full list of countries included in the primary dataset. These were retained but their incompleteness is made explicit in the discussion of the meta-analysis results.
Synthesize findings (answering review question)	Figures and Tables for visual inspection of studies characteristics, summary statistics and econometric results
Communicate and engage	Discussion of the results in Chapter 2 and further discussion in terms of policy implications of the analysis in Chapter 5

Source: Author's elaborations from Gough (2007) Figure 2, and Gough (2013).

References

Gough, D. (2007) 'Weight of Evidence: a framework for the appraisal of the quality and relevance of evidence', *Research Papers in Education* 22 (2): 213-228.

Gough, D. (2013) *Introduction to systematic reviews (I)*, online video from the 'Evidence Informed Policy and Practice in Education in Europe' workshop, 13 September 2012, Trakai, Lithuania. Accessed 15 July 2013, <http://www.youtube.com/watch?feature=endscreen&NR=1&v=apWAql2TQKM>.

Gough, D. and D. Elbourne (2002) 'Systematic Research synthesis to Inform Policy, Practice and Democratic Debate', *Social Policy and Society* 1 (3): 225-236.

Jackson, G.B. (1980) 'Methods for Integrative Reviews', *Review of Educational Research* 50 (3): 438-460.

Oliver, S. (1999), 'Users of health services: following their agenda', in S. Hood, B. Mayall, and S. Oliver (eds.), *Critical issues in Social Research: Power and Prejudice*. Buckingham: Open University Press.

Chapter 3
Weather variability and food consumption
Evidence from rural Uganda[20]

Abstract

This multidisciplinary study considers the impact of short-term weather variations on food consumption of 488 rural households in Uganda. I combine World bank LSMS household panel data with data on rainfall, number of rainy days, maximum and minimum temperatures in the period 2005/06-2009/10. Results show that on average a 1% increase in maximum temperature would reduce food consumption by 3 to 5 while precipitation amount and distribution would not affect households food consumption. Household land ownership seems to mitigate adverse variations in precipitations amount (rainfall millimeters) depending on the size of both the rainfall variation and land owned. Triangulating the findings of the econometric model with qualitative interviews and the analysis of the agricultural sector recent developments, I argue that households are involved in ex-ante smoothing strategies while the size of land owned and the reduction of non-consumption expenditures seem to partially offset adverse rainfall variations.

JEL: I31; O12; O44; Q12; Q14.

Keywords: weather variability; risk; food consumption; Uganda.

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[20] This chapter largely benefits from comments from Arjun S. Bedi, ISS staff and participants to the conferences "Economic Development in Africa " at the Centre for the Study of the African Economies, Oxford University, UK (16-20 March 2013), the "5th EAAE Phd Workshop" organized by the European Association of Agricultural Economists in Leuven (Belgium, 29-31 May 2013) and the conference "Between crisis and development: which role for the bioeconomy" in Parma (Italy, 6-7 June 2013). I also gratefully acknowledge the funding from the Doctoral school for the participation at the CSAE conference.

3.1 Introduction

In the wake of the current debate on the effects of climate change on poor households in developing countries, the analysis of the effects of extreme events and weather variability on households welfare and household coping strategies still permeates the academic discussions on the role of risk, shocks and vulnerability as perpetrators of poverty. As entrepreneurs and proponents of agricultural development have agreed, individuals and households in developing countries, would be more affected from changes in weather patterns due to their high degree of vulnerability (Cooper et al., 2008: 25) combined with their high dependence on the rain-fed agricultural sector (Skoufias et al., 2011: 2). By contrast, to the extent that individuals and households are able to appropriate or develop technologies and adjust their behavior to mitigate the impacts of weather changes, they can cope or, as the literature on climate change states, *adapt*, to climatic shocks (Nordhaus, 1993: 14). Hence, a review of the multiple channels through which climatic shocks can affect household welfare is needed to assess the state of art and case-specific analyses are needed to understand the set of behavioral and technical changes that households may adopt to counteract welfare losses.

Building on these premises, this chapter discusses the chain of direct and indirect effects of simple extreme events on rural households welfare engaging with the findings of other disciplines (biology, medical science, agrarian studies) and referring to the existing microeconomic literature on the impact of weather variability on selected welfare indicators. This discussion is then used as a framework to analyze the effects of rainfall, number of rainy days, maximum and minimum temperatures variability on household food consumption in Uganda. Increasing concerns about the adverse effects of climate change (Magrath, 2008; NAPA, 2007) exacerbating the already assessed high vulnerability to weather changes of rural households in the country (MAAIF, 2010; Okori et al., 2009), recent food security issues (Shively and Hao, 2012) and the lack of a comprehensive analysis of the effects of weather variability on household food consumption in Uganda motivate this analysis.

The study is conducted using mixed methods. The quantitative analysis uses a household panel dataset provided by the World Bank Living Standard Measurement Study (LSMS) on Uganda covering the period 2005/06-2009/10. I concentrate on households reported as living in rural areas to specifically focus on the rural dimension of the consequences of simple extreme events. Households interviewed in the same season in both rounds only are analyzed to rule out seasonal patterns in the outcome variable.[21] The LSMS subsample is merged with rainfall and temperatures recordings from the Department of Meteorology at the Ugandan Ministry of Water and Environment (UDOM). Results of the econometric model are then discussed in light of the results of qualitative interviews conducted by Magrath (2008), Okonya et al. (2013) and Osbahr et al. (2011) assessing household perceptions of climate change effects in the country. Finally, the analysis of the agricultural sector performance in recent years helps to reveal recent possible production patterns changes in response to climate change related increasing weather variability.

The results show that weather variations seem to have adverse effects on food consumption, depending on the weather indicator considered. On average 1% increase in maximum temperature would reduce food consumption by 3 to 5%, suggesting households vulnerability to temperature changes. On the other hand, precipitation amount and distribution do not seem to household's food consumption. Household land ownership seems to mitigate adverse variations in precipitations amount (rainfall millimeters) depending on the size of both the rainfall variation and land owned. Moreover, if food consumption doesn't seem to be highly affected by rainfall variations, I find that non-consumption expenditures such as expenditures on funerals and social functions, and outgoing remittances would experience 5 to 20 percent reductions respectively in the case of a 10% decrease in precipitations. Triangulating the findings of the econometric analysis with the findings of the agricultural sector performance review I argue that households would be involved in *ex-ante* smoothing strategies (crop choices) that help to reduce adverse effects of rainfall variations on food consumption.

The relevance of this work is multiple. First of all, adding to the existing literature on climatic shocks in developing countries (Dercon, 1996; Kazianga and Udry, 2006) the paper analyzes the effects of temperature variations on household food consumption. Second, the analysis provides evidence that poor households in rural areas are able to some extent to adjust to rainfall variability. Third, I use different approaches ranging from qualitative to quantitative analysis and move on the boundaries of different disciplines (economics, biology and agriculture) to sustain the results. Finally I exploit a dataset and focus on a context (Uganda) not much explored as far as the relationship between food consumption and weather variations is concerned.

The remainder of this paper is organized as follows. Section 3.2 contextualize climatic shocks in the literature on shocks in developing countries and analyze the channels through which they affect households welfare. The possible coping and adapting strategies are briefly

[21] Further estimations on the overall household panel accounting for the season of interview show robustness of the

introduced. Section 3.3 describes the socio-economic and weather characteristics of rural households in Uganda while Section 3.4 discusses data and empirical model. Section 3.5 presents the results and robustness checks. Section 3.6 triangulates the findings and Section 3.7 concludes.

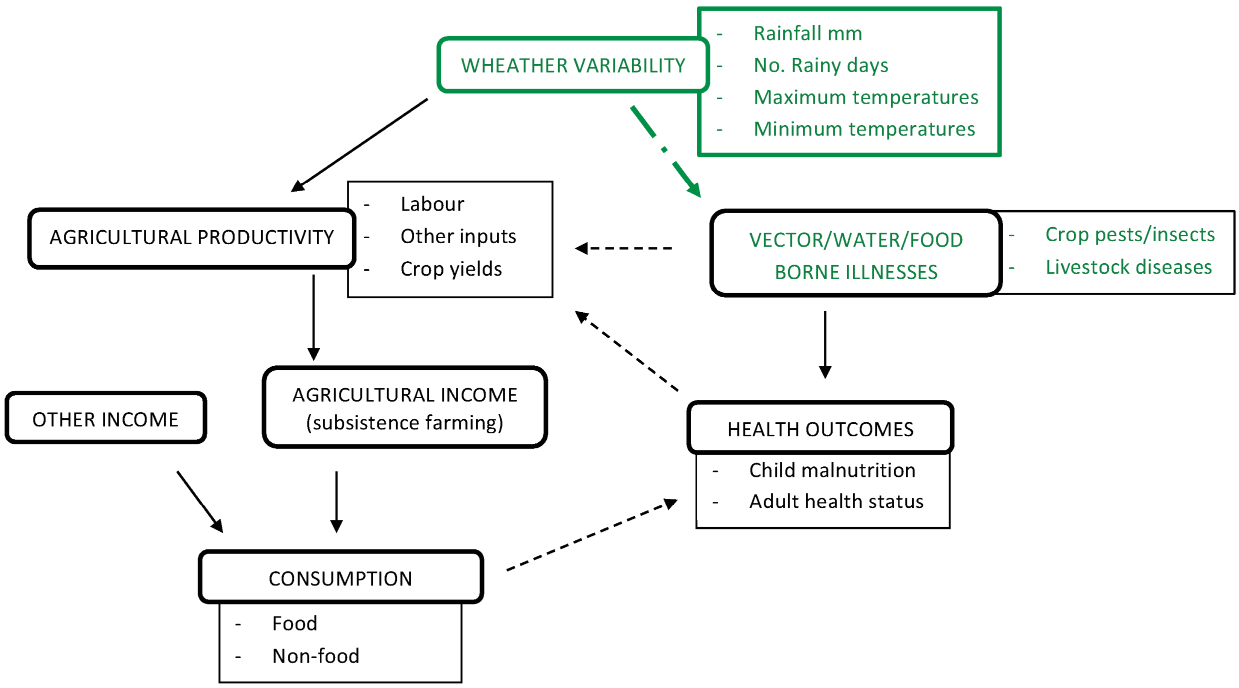
3.2 Analytical framework

3.2.1 Weather variability and welfare impacts

Climatic shocks have always attracted particular attention in the literature on the determinants of poverty due to their ability to influence potentially all the different measurable dimensions of welfare (Tol, 2009) and their ability to affect all the households in a given community at the same time (covariant shock as opposed to household-specific idiosyncratic shocks). As clarified in the introduction, natural extremes events are classified by IPCC (2001) into simple and complex extremes extreme events. Higher maximum and minimum temperatures (with the connected increase of hot days and heat waves) and the increase in the intensity of precipitation events are examples of extreme simple events or *weather variability* as referred to the usual pattern of weather indicators. Increasing occurrence of droughts and floods, especially when precipitations are associated with El Niño events, or storms and tropical cyclones and more variability in the monsoon season are examples of extreme complex events. In this chapter I particularly consider the effects of weather variability, acknowledging that complex events can be considered nothing but simple extreme events that occur in a more disruptive way, due to their specific duration and temporal shape (Anderson, 1994: 555). In the analysis of weather variability potential effects on household welfare I follow Skoufias *et al.* (2011) and discuss some aspects of rural households welfare. Figure 3.1 helps to visualize the potential chain of effects. The box "weather variability" includes the climatic shocks considered in this study while the other boxes include household activities and, for completeness, other climatic shocks (biological hazards such as crop pests and livestock diseases). The solid lines represent direct effects, the dashed lines represent indirect effects and the dashed-dotted line represents linkages between different types of climatic shocks.

results countrywide.

Figure 3.1 Weather variability and its impact on household welfare.



Source*:* Adapted from Skoufias *et al.* (2011).

First of all, the close connection between the agricultural sector and the natural system, and the importance of agriculture in developing countries make the impact of adverse weather variations potentially harmful for rural households and for the performance of the entire economy. In the short-term weather variations may have a direct impact on agricultural productivity and income because higher temperatures and changing rainfall patterns are likely to modify the hydrological cycle, ultimately affecting crop yields and total factor productivity (IPCC, 2001: 31). Weather changes may have short-term effects on crop yields through changes in temperatures when they exceed the optimal thresholds at which crops develop (Lansigan *et al.*, 2000; Prasad *et al.*, 2008). Similarly, mismatches between the amount of water received/required and its potential evapotranspiration during the growing and harvesting seasons, and the timing of the water stresses faced by the crops may affect the agricultural productivity (Otegui *et al.*, 1995; Wopereis *et al.*, 1996). On the other side, when water comes or does not come in extreme quantities (floods or droughts) its potential impact can be very high due to the losses of lives and infrastructures (IPCC, 2001: 29). Instability or a decrease in agricultural income may have effects on food consumption (as share of production or income) depending on the nature of the agricultural activity. When the agricultural activity is of subsistence nature the effect on consumption is through the quantities produced while in the case of market-oriented activity the effect can be both through quantities and prices. Positive net effect on household income and consumption may occur in the case of market-oriented agriculture (Singh et al., 1986) but this does not seem to apply in Uganda due to the prevalence of subsistence agriculture[22]. The impact of decreased income may affect different types of consumption in different ways. Generally, food consumption is likely to decrease less than non-food consumption (Skoufias and Quisumbing, 2005), in some cases depending on household characteristics such as the sex of the income earner (Duflo and Udry, 2004). Moreover, even if yields are not affected, erratic weather may stress the crops and lower the quality of the harvest, pushing the household to purchase food.

The indirect (dashed arrows) impacts of weather changes are mainly on agricultural productivity and come primarily from two channels: the development of vector/water/food-borne diseases (biological shocks) and health and malnutrition effects on children and adults. I will explore these effects more thoroughly in Chapter 4.

The multiple effects of weather variability will take place in different degrees depending on the *ex-ante* and *ex-post* coping mechanism that households are able to put in place. Households can adopt two kinds of risk coping strategies: income smoothing and consumption smoothing (Morduch, 1995: 104). The two strategies differ in the time horizon over which they deal with shocks. Income smoothing is aimed to prevent or mitigate the effects of shocks before they occur while consumption smoothing is concerned with the effects of shocks after they have taken place. Income smoothing includes decisions concerning production, employment and the diversification of the economic activities. For example, on the production side rural households may choose to cultivate different types of crops or inputs intensities (Morduch, 1995: 104). Although this behavior may insure a certain amount of income, it may also have adverse effect on household final welfare. For example, Dercon (1996) found that the absence of developed markets for credit combined with the lack of accessibility to off-farm labor, provided an incentive to cultivate low-risk, low-return crops (sweet potatoes) to rural households in Shinyaga District of Tanzania. A poverty trap of low-income and assets ownership, induced low-risk, low-return crop choices and hence low-income and assets accumulation seemed to capture households in the area (Dercon, 1996). Analogously, intercropping (that combines mixed cropping with field fragmentation) or adoption of new production technologies (like high-

[22] This argument is further supported by Benson *et al.* (Benson et al., 2008). The authors analysed the mechanism of global and regional prices transmission and its welfare effects in Uganda suggesting that not many would benefit from rising food prices. In fact, only 12 to 27% of the population seems to be a net seller of food.

yielding varieties-HYV and fertilizers) may lower the risk of agricultural activity. Behavioral norms and household specific characteristics would play a further important role in the decision process (Foster and Rosenzweig, 1995). On the other side, *ex-post* consumption smoothing comprises decisions regarding borrowing and saving, selling or buying non financial assets, modifying the labor supply and making use of formal/informal insurance mechanisms (Bardhan and Udry, 1999: 95).

3.2.2 Empirical literature

Drawing on the framework outlined above, there is a well-developed empirical literature that has examined the effects of weather variations on agricultural production, income, consumption and savings. The following review considers two aspects: methodologies used to operationalize weather and climate variations and coping strategies.

Operationalizing weather

I identified four strands in the literature depending on the methodology adopted and the scopes of the studies.

First, agronomic models simulate crop growth, development and yields under different climate scenarios. Agronomic models rely on empirical or experimental production functions representing soil-plant-atmosphere dynamics and including relevant determinants of crop performance such as temperature, precipitation and carbon dioxide levels (Mendelsohn et al., 1994). Many crop models exist worldwide for a variety of crops (land uses) and incorporate the whole distribution of weather outcomes on a daily basis relying on interpolated gridded climate normals for current conditions. DSSAT, APSIM and CERES are some of the most used (Rivington and Koo, 2010). Simulations of future rainfall and temperature elaborated by Atmosphere-Ocean Global Circulation Models (AOGCMs) and emissions scenarios (SRES) can then be fitted into agronomic models to estimate crop yield response to weather and climate change. Global assessments modeling wheat, rice, maize and soybean have emphasized that global crop production might only slightly decrease if temperature increases but developing countries will be more affected (Rosenzweig and Parry, 1994; Parry et al., 2004). On a regional basis, using CERES-Maize and BEANGRO-DSSAT crop models, Thornton et al. (2009) simulate maize and beans yields in the bimodal East-African region when grown in current climatic conditions and their yields response to projected changes in temperature (1.0 to 1.8 °C and 1.6 to 2.8°C SRES scenarios) and rainfall (wetter and dryer AOCGMs scenarios). Simulations suggested a 1 to 15% decline in production (with 75% primary-season maize and

25% secondary-season beans contribution) depending on the temperature and rainfall scenario considered. In a subsequent study Thornton et al. (2010) also downscale simulations to account for climatic and topographic variability in the East African region showing about 5 to 35% increases in maize and bean production in temperate/tropical highland but production decreases in humid-sub humid and arid-semiarid areas[23], with Uganda being one of the lowest performers.

Many other examples consider other regions of the world or specific countries, however agronomic models are criticized for reliance on extremely careful parameters calibration (often done in temperate systems) and failure to consider economic and human capital factors that might affect farmers' decisions. These drawbacks would result in overestimation of the simulated damages (Mendelsohn et al., 1994; Schlenker and Roberts, 2008; Di Falco et al., 2012) or misleading representations of relevant processes in developing countries. Thornton et al. (2010) acknowledge these limitations but suggest underestimation of production responses due to failure to account for increasing weather variability, biotic and abiotic stresses and high population growth, thus requiring adaptation strategies tailored at the household and community level in order to reduce poverty and food insecurity.

The second strand, Ricardian (or hedonic) models, attempt to correct agronomic models using economic data on land values or farm net revenues, thus accounting for the whole agricultural sector (Schlenker and Roberts, 2008). Using cross-section data, Ricardian studies have attempted to identify the extent to which both rainfall and temperature variability determine crop choices (Kurukulasuriya and Mendelsohn, 2008; Minten and Barrett, 2008), crop yields (Schlenker and Roberts, 2008; Di Falco et al., 2012; Barnwal and Kotani, 2013) and net revenues from agriculture (Deressa, 2007; Deschênes and Greenstone, 2007; Kabubo-Mariara and Karanja, 2007; Kurukulasuriya and Mendelsohn, 2008; Molua, 2009). As for weather indicators, Ricardian models generally use rainfall millimeters and temperature °C long-term average seasonal levels calculated as the simple average of the monthly estimates for each season between a certain year (for example 1970) and some years before the relevant census year[24]. Since land values or farm net revenues are assumed to include future climate variations and farmers behavioral responses/adaptation, climate scenarios can be computed to estimate productivity changes (Di Falco et al., 2012). The main concern with Ricardian models is spatial correlation between climate and environmental variables so that omitted variables bias could occur if critical time-independent location-specific factors (such as soil types or farmers skills) are not included

[23] Simulations to 2030.

[24] According to Deschênes and Greenstone (2007) the standard upper limit would be two years before the census year.

in the regression model (Schlenker and Roberts, 2008; Barnwal and Kotani, 2013). Deschênes and Greenstone (2007), Schlenker and Roberts (2008) and Barnwal and Kotani (2013) use then panel data to address the omitted variables problem. Deschênes and Greenstone (2007) use a county-level panel dataset of US agriculture and county-specific annual weather deviations from county averages (adjusted for state-wide shocks) modeling weather variables using growing season degree-days and growing season precipitation and respective squared terms. The model estimates farm agricultural profits (since annual weather should not influence agricultural land values) and includes county and year fixed effects to account for unobserved county-specific time-invariant determinants and county annual differences in agricultural profits. Orthogonality of weather variations to unobserved determinants would insure unbiased estimates. Deschênes and Greenstone find no statistically significant effects of weather on US agricultural profits in the short run and show beneficial effects on profits and crop yields under climate change scenarios. Similarly, Schlenker and Roberts (2008) use US county-level panel data on crop yields and fine scale historical daily temperature (that allow to keep within-county variation) including county fixed effects in the estimations. In contrast with Deschênes and Greenstone (2007) they find large and negative (non-linear) effects of temperature changes (see Fisher et al. 2012 for a discussion of the sources of different results). Barnwal and Kotani (2013) analyze rice yields in India using a panel dataset and operationalizing weather data as average temperature (°C) and total precipitation (cm) including daily temperature and precipitation standard deviations, a variable accounting for rainfall intensity (calculated as the proportion of maximum monthly rain to annual rain) and a dummy to account for drought periods. Applying quintile regressions Barnwal and Kotani find different impacts of weather variables across the yield distribution depending also on agro climatic zones and crop seasonality (summer/winter). In line with the conclusions of the agronomic study of Thornton et al. (2010), Barnwal and Kotani suggest the need to consider possible changes in farmers' crop choices and location- and season- specific adaptation.

The approach of Deschênes and Greenstone (2007) bridges Ricardian analyses with a third strand of literature examining the effects of "current" annual/seasonal rainfall deviations from long-term means in household level analyses of agricultural income and subsequently savings/consumption (Paxson, 1992; Jacoby and Skoufias, 1997; Ersado et al., 2003). Paxson (1992) and Jacoby and Skoufias (1997) using panel datasets find that households would smooth transitory income variations related to rainfall changes from their normals. Ersado et al. (2003) instead use two separate cross sections and show that consumption would be positively/negatively affected depending on the sign of rainfall variation. Similarly, Dercon

(2004) analyze the effects of rainfall levels directly on consumption (with panel data) showing significant rainfall effects on household food consumption.

Finally, the fourth strand of the literature considers the effect of specific extreme rainfall events on food security and poverty (Reardon et al., 1998; Reardon and Taylor, 1996) and/or examines the effect of specific extreme rainfall events on crop income and cereals output (Fafchamps et al., 1998), income and consumption (Kazianga and Udry, 2006) and consumption (Skoufias and Vinha, 2013; Thomas et al., 2010) using panel datasets. Different extreme-event indicators are used across the studies: total annual rainfall (Fafchamps et al., 2008), rainfall deviations from long-term means in (Kazianga and Udry, 2006), rainfall shock dummies to account if the annual or seasonal rainfall (growing degree-days) experienced by the household was one or two standard deviations lower (negative shock) or higher (positive shock) than the long-term mean (Skoufias and Vinha, 2013). Clearly the heterogeneity in weather extremes measures is very high, whether different measures could influence the results has still to be investigated. Thomas et al. (2010) provide a first attempt discussing advantages and disadvantages of using subjective (self-reported) measures of climatic shocks (scarcely used when dealing with production, income and consumption due to methodological and practical shortcomings) and objective measures derived from weather data. In the latter case Thomas et al. emphasize the low resolution of meteorological databases and the further heterogeneity in the procedure of assignment of the weather measures (from simple Euclidean distance as in Paxson 1992, to different interpolation techniques as in most recent studies with higher data availability). Notably, while there is a relative abundance of studies that have considered the effect of rainfall variations/extreme events on household consumption, this is not the case for temperature extremes. Skoufias and Vinha (2013) is a relatively rare study that examines the effect of both variations in rainfall and temperature on household consumption. Rainfall extremes were generally found to have negative effects on the outcomes considered except in Skoufias and Vinha which show an average ability of rural household in Mexico to smooth consumption with some location and period specific variations for both rainfall and temperature shocks.

The analysis in this chapter can be placed in the third strand of literature and uses both rainfall (1960 onwards) and temperature data (1980 onwards) to construct measures of weather variability. To my knowledge, available international satellite data for Uganda have fairly poor resolution, hence I rely on weather data from 13 synoptic stations spread across the country. Households are matched to a specific synoptic station based on their proximity. The average distance of households from a synoptic station is 32 kilometers. Following Dercon (2004) I measure rainfall and temperature taking the logarithm of seasonal rainfall millimeters, number of rainy days (to account for rainfall distribution) and minimum and maximum temperatures. The analysis of weather variability in Uganda is conducted in a one-step panel fixed effects estimation to counteract the high data intensity and approximation required by two-step estimation.

Coping strategies

According to Rosenzweig and Binswanger (1993) among the factors that determine agricultural productivity and farm output weather would mostly influence household welfare due to its spatial covariance. To the extent that covariant risk cannot be insured, households would involve in *ex-ante* production decisions, while covariate shocks would result as uninsured in most low-income contexts. In fact, Rosenzweig and Binswanger find that the effect of weather-independent farm income on food consumption is just 0.6% of the total farm income in rural India. Other empirical evidence supports their arguments and findings but concentrate mainly on *ex-post* coping strategies.

Townsend (1994) shows that consumption of households in southern India co-moves with village average consumption while idiosyncratic shocks would not affect household consumption thanks to risk-sharing mechanisms. Similarly, Dercon (2004) finds that risk sharing at the village level would insure 342 households in rural Ethiopia from illnesses and crop and livestock shocks at the household level, leaving village-rainfall shocks in the year before and in preceding years uninsured (covariant rainfall shocks seems to have persistent effects). Townsend (1994) highlights other risk-bearing institutions: borrowing, purchasing and selling assets, grain storage and crops and plots diversification. Jalan and Ravallion (1999) then analyze income risk in rural China using the approach of Townsend (1994) but also controlling for household wealth and show that not accounting for other risk-bearing factors can lead to under/over estimation of the effects of the coping strategy considered. The survey data of Kinsey and Burger (1998) suggest that livestock sales were very important to compensate possible food shortages following drought periods in Zimbabwe. By contrast, Fafchamps et al. (1998) and Kazianga and Udry (2006) find little evidence that livestock sales in Burkina Faso follow cereal output, crop income and consumption shocks due to droughts. Paxson (1992) analyze the response of saving to rainfall-induced transitory income in Thailand. Assuming that rainfall variations will produce income shocks without having effects on consumption, Paxson shows that farm households would save higher share of transitory rather than non-transitory income. Moreover, other households non-consumption expenditures or additional incomes such as gifts and informal loans can vary in response to weather variations. For example, Fafchamps and Lund (2003) show increasing incoming gifts and informal loans in the case of idiosyncratic shock, decreasing in case all the households in the household network experience the same shock.

Turning to the context of Uganda, a number of recent papers have analyzed the consequences of changing weather patterns in Uganda and the coping strategies that may have been adopted to deal with these changes.

Magrath (2008), based mainly on qualitative interviews conducted with rural households, report that due to erratic rainfall in the first rainy season (March to May/June), droughts are more frequent and crop yields and plant varieties are declining. Employing a similar methodological approach, Okori et al. (2009) argue that farmers in Lira and Kitgum districts of Northern Uganda perceived the decline and unexpected timing of rainfall as major causes of decreased food production and famines. Mwerera et al. (2010) find that 89% of the surveyed farmers in Kabale and Nakasongla districts (in Western and Central Uganda respectively) experienced droughts leading to a 39.2% decrease in crop yield and 35.1% decline in income.

Adopting a quantitative approach, Asiimwe and Mpuga (2007) analyze the effect of variations in rainfall on the income and consumption of rural Ugandan households. The authors work with repeated cross section survey data (1999/2000 and 2002/2003) and rainfall data from the Statistical Abstract of the Uganda Bureau of Statistics. Using rainfall deviations from the long-term means they find a 51.7 percent decline in income of rural households during the first rainy season.[25] However, they do not find a clear-cut effect on consumption. The authors argue that the decline in income with no effect on consumption suggests the use of consumption smoothing strategies (Asiimwe and Mpuga, 2007: 18).[26]

While there is some evidence of a decline in income and crop yields the qualitative and quantitative also provides evidence of ex ante and ex post income and consumption smoothing at work. Magrath (2008: 7) quotes an interview with the Executive Director of the Karughe Farmers Partnership in the Kasese district who states:

> "Because of the current weather changes the yields have completely gone down. We used to have much more rainfall than we are having now, that's one big change, and to me this area is warmer than 20 years ago. Until about 1988 the climate was okay, we had two rainy seasons and they were very reliable. Now the March to June season in particular isn't reliable, which doesn't favor the crops

[25] Rainfall changes were measured as the difference between current seasonal rains and the long-term mean, divided by the long term mean, for the planting and harvesting seasons in the six months preceding the date of interview of the household (Asiimwe and Mpuga, 2007: 11)

[26] The estimations could be downward biased in the case the survey years were particularly different from the others. For example, if 1999/2000 was a year of massive rains as compared to the usual rainfall pattern, the long-term mean calculated including the 1999/2000 data would spread the effect of that particular year on the other data, lowering the magnitude of the shock in the analysis and compromising the ability of the model to capture the effects of the shock on the outcome variable.

we grow. Rain might stop in April. Because of the shortened rains you have to go for early maturing varieties and now people are trying to select these." (Magrath, 2008: 7).

It is also possible to counteract the effects of increases in temperature by using heat-resistant crop varieties or changing the crop-mix. For instance, intercropping cassava with maize can lower the temperature of the soil and allow higher yields for cassava also thanks to the improved soil moisture and earthworms activity (Olasantan et al., 1996: 149-50). Since maize grows faster and develops high leaf area, cassava can enjoy a lower soil temperature during its first three months of growth, counteracting the rise in temperatures in the ecosystem and leading to higher yields. The same mechanism may also occur by intercropping maize or sorghum with potato and groundnut crops.

3.3 Weather variability and agriculture in Uganda

3.3.1 Background

Uganda is a landlocked country classified by the World Bank as a low-income nation. Poverty in Uganda is high but declining in recent years. The percentage of population living with or less than 2$ a day (PPP) declined from 86% of the mid-nineties to about 76% in 2006, reaching 65% in 2009 (World Bank, 2011). As Table 3.1 and 3.2 show, although the agricultural sector share of total GDP decreased during the years, the country is still highly reliant on agriculture for the generation of its income, the agricultural sector employing more than 65% of the labor force (World Bank, 2011). In the survey data about rural Uganda about 77% of the individuals are engaged in subsistence rain-fed agriculture while only 2-3% work in the market-oriented agricultural sector (see Table 3.3).

Table 3.1 Per capita GDP (constant 2000 USD) and value added per sector (% GDP).

	1990-1994[a]	1995-1999[a]	2000-2004	2005-2010
GDP per capita (constant 2000 UDS)	193.99	239.11	273.38	345.13
Agriculture value added (% GDP)	52.40	43.41	26.60	24.60
Industry value added (% GDP)	12.72	17.17	23.23	25.75
Services value added (% GDP)	34.88	39.42	50.17	49.65

Source: World Bank (2011b)

Note: [a]The base year for the underlying series until 1998 is 1997/98, after 1998 the base year is 2001/2002.

Table 3.2 Employment per sector (% of total employment).

	2002	2005	2009
Agriculture	65.50	71.60	65.60
Industry	6.50	4.50	6.00
Services	22.00	23.20	28.40

Source*:* World Bank (2011b)

Note: Data on employment per sector are available only for the years presented in the table when a national household survey was conducted.

Table 3.3 Distribution of rural household's individuals in Uganda by occupations.

	Full sample NHS (3,123 households)		Study sample (488 households)	
Occupation	2005	2009	2005	2009
Subsistence agricultural and fishery workers				
Subsistence agricultural workers	77.94%	76.87%	79.17%	79.21%
Subsistence animal rearing	2.80%	3.69%	1.93%	3.55%
Subsistence fishery and related	0.63%	0.18%	0.43%	0.24%
Market-oriented skilled agricultural and fishery	2.60%	2.84%	2.00%	2.70%
Elementary occupations				
Agricultural, fishery and related	3.39%	2.46%	3.00%	2.22%
Other elementary occupations	2.78%	3.78%	2.27%	3.00%
Other job categories	9.86%	10.18%	11.2%	9.08%
Total	100%	100%	100%	100%

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel.

Data on production, yields and harvested area for selected crops are reported in Table 3.4 for selected years. The most important crops in terms of output are plantains, cassava, sweet potatoes and maize. The agricultural production at the national level has generally increased for almost all the crops considered but this is mainly due to an increase in the amount of land cultivated (yields remained fairly stable or decreased for some crops). High population growth causing soil erosion and degradation has however decreased per capita production (Pender et al., 2004). Indeed, the studies by Benin *et al.* (2007), James (2010) and Okoboi et al. (2013) reveal that the government efforts to modernize agricultural practices were only partially effective and the increase in production was mainly due to the progressive extension of land cultivated, especially for food staples - maize, potatoes, beans. Note that coffee, the traditional cash crop, experienced a decrease in the land cultivated between 2000 and 2010.

Table 3.4 Production, yields and hectares harvested for selected crops in selected years.

	Production (1000 Tons)				Yield (Kg/Ha)				Hectares harvested (1000 Ha)			
	2000	2005	2010	% change	2000	2005	2010	% change	2000	2005	2010	% change
Banana	610	563	600	*-1.64*	4519	3976	4196	*-7.15*	135	142	143	*5.93*
Beans	420	468	455	*8.33*	601	577	489	*-18.64*	699	828	930	*33.05*
Cassava	4966	5576	5282	*6.36*	12384	14408	12728	*2.78*	401	387	415	*3.49*
Coffee	143	158	162	*13.29*	477	601	600	*25.79*	301	263	270	*-10.30*
Groundnuts	139	159	172	*23.74*	699	707	732	*4.72*	199	225	235	*18.09*
Maize	1096	1170	1373	*25.27*	1742	1500	1543	*-11.42*	629	780	890	*41.49*
Plantains	9428	9045	9550	*1.29*	5900	5400	5618	*-4.78*	1598	1675	1700	*6.38*
Potatoes	478	585	695	*45.40*	7029	6802	6814	*-3.06*	68	86	102	*50.00*
Sorghum	361	449	500	*38.50*	1289	1527	1515	*17.53*	280	294	330	*17.86*
Sweet potatoes	2398	2604	2838	*18.35*	4321	4414	4577	*5.92*	555	590	620	*11.71*
Total	20039	20777	21627	*7.92*	38961	39912	38812	0.38	4865	5270	5635	15.83
Population (million)	24.2	28.4	33.4	*38.02*								

Source: FAO (2012) for data on agricultural sector and World Bank (2011) for population data.

Table 3.5 presents data on production and land allocation for selected crops for the 488 households considered. High value cash crops have traditionally been coffee, tea, cotton, tobacco and banana but, besides banana and coffee, these crops account only for a very small portions of households agricultural income (Betz, 2009; Kasente et al., 2002). Banana (food) is cultivated both as food and cash crop but its cultivation only partially followed the increasing trend of other major (staple) food crops: maize, cassava, sweet potatoes and beans.

Table 3.5 Average hectares cultivated for selected crops in the LSMS sample.

	Pure stand				Intercropped			
Crop name	2004.2	2005.1	2009.1	2009.2	2004.2	2005.1	2009.1	2009.2
Food crops								
Maize	0.18	0.17	0.25	0.28	0.44	0.60	0.54	0.34
Cassava	0.21	0.27	0.39	0.23	0.31	0.36	0.41	0.28
Sweet potatoes	0.16	0.14	0.14	0.19	0.04	0.07	0.07	0.06
Beans	0.07	0.07	0.09	0.12	0.41	0.44	0.45	0.34
Sorghum	0.07	0.09	0.11	0.12	0.07	0.36	0.08	0.05
Finger millet	0.04	0.05	0.04	0.08	0.05	0.20	0.06	0.04
Groundnuts	0.05	0.07	0.05	0.17	0.07	0.11	0.14	0.07
Banana beer	0.04	0.05	0.02	0.02	0.11	0.11	0.05	0.08
Irish potatoes	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Cash crops								
Banana food	0.10	0.10	0.15	0.15	0.35	0.40	0.28	0.30
Coffee all	0.04	0.04	0.07	0.05	0.21	0.25	0.24	0.23
Tea	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Tobacco	0.00	0.03	0.00	0.02	0.00	0.00	0.00	0.00
Simsim	0.08	0.02	0.08	0.03	0.05	0.02	0.01	0.02
Cotton	0.07	0.01	0.01	0.00	0.06	0.02	0.00	0.01
Pastures	1.86	1.90	0.09	0.10	0.01	0.09	0.00	0.00
Other	3.11	2.70	0.32	0.45	0.28	0.44	0.32	0.21

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel.

Note: The LSMS agricultural questionnaire was referred to the second agricultural season 2004 and first agricultural season 2005 in the first round (columns 04.2 and 05.1 in the table) while in the second round it was referred to the first and second agricultural season 2009 (columns 09.1 and 09.2 in the table).

Considering the concerns on food security, this increase seems an attempt to insure against food shortages: maize grows fast and can be both eaten or sold if cash is needed, cassava is relatively easy to grow and store, sweet potatoes mature fast, require low labor input (as cassava) while beans are rich in proteins, are the first crop to mature after the dry season and can be stored until the following season (Bagamba et al., 2008; Kasente et al., 2002). Improved varieties of all these crops could generate higher margins, up to five in the case of cassava (Kraybill and Kidoido, 2009), however underinvestment and wrong incentives given by the government (such as 5% GDP ceiling to expenditures in agriculture and the tax-reduction on hoes) constitute major impediments to the adoption of high-technology inputs and modernization (Hickey, 2013: 202). Table 3.6 presents the prevailing agricultural practices. Note the low use of improved seeds (although increasing), organic and chemical fertilizers and pesticides. Between the two rounds of the survey the most important change occurred in the land tenure system, following the implementation of the land reform act.

Table 3.6 Agricultural practices – 488 households sample.

	2005/06		2009/10	
Has your household cultivated crops? YES	90.97%		93.42%	
Land tenure – Owned land (YES)	(85.81%)		(91.77%)	
Freehold		5.60%		33.57%
Leasehold		1.62%		1.64%
Mailo		11.21%		3.76%
Customary		80.20%		60.80%
Other		5.60%		33.57%
Land tenure – User rights (YES)	(44.84%)		(39.74%)	
Freehold		4.60%		30.55%
Leasehold		4.60%		6.19%
Mailo		23.02%		6.18%
Customary		64.72%		50.91%
Other		3.07%		5.45%
	2004.2	2005.1	2009.1	2009.2
Seeds used				
Local	93.80%	94.23%		
Improved	6.20%	5.42%		
Mixed	-	0.36%		
Newly purchased seeds			(31.14%)	(18.83%)
Local	-	-	79.70%	80.00%
Improved	-	-	20.30%	20.00%
Use of organic fertilizers (YES)	6.96%	4.54	4.50	3.83
Use of chemical fertilizers (YES)	0.50%	0.87	1.73	0.46
Use of pesticides (YES)	3.41%	1.87	3.84	3.15
Work of household members				
Person days	29	23	37	35
(standard deviation)	(34)	(26)	(56)	(46)
Work of hired labor (YES)	(22.45%)	(17.99%)	(29.59%)	(31.65%)
Average person days	13	13	6	3
(standard deviation)	(21)	(19)	(23)	(11)

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel.

Note: The LSMS agricultural questionnaire was referred to the second agricultural season 2004 and first agricultural season 2005 in the first round (columns 2004.2 and 2005.1 in the table) while in the second round it was referred to the first and second agricultural season 2009 (columns 2009.1 and 2009.2 in the table).

3.3.2 Weather and variability

Uganda's climate is influenced by the Inter-Tropical Convergence Zone, whose position varies over the year: from October to December it goes to the southern part of the country while from March to May it returns in the northern part (McSweeney et al., 2007: 1). Consequently, the prevalent rainfall pattern is bimodal with the aforementioned two rainy seasons, with rains falling with the northeasterly winds coming from the Indian Ocean. The two agricultural seasons are composed by a dry season and a rainy season. The first agricultural season goes from December to May, December-January-February being the first dry season in which the fields are prepared after the harvest for the coming first rainy season from March to May. The second agricultural season starts in June with the harvest and preparation of fields until August, leading to the second planting season from September to November (Asiimwe and Mpuga, 2007: 10) (see Figure 3.2 for a graphical representation of the agricultural cycle).

The country is particularly vulnerable to weather changes and, more generally, to climatic shocks due to individuals and households high dependence on rain-fed agriculture (Mubiru et al., 2012: 1). Rough estimates on the disaster profile of Uganda drawn from the Emergency Events Database (EM-DAT) maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Leuven, Belgium[27] show that droughts and floods are the phenomena that mostly have affected the Ugandan population (EM-DAT, 2012). More than 10% of Ugandans are exposed to the risk of droughts and the country is listed as 19th out of 184 countries in the human exposure ranking for this type of hazard (ISDR, 2009).

The National Adaptation Plan of Action (NAPA) elaborated in 2007 summarizes the channels through which climate change is affecting and may affect Uganda's development, confirming the approach of the theoretical framework outlined in the previous section.

A recent report from Oxfam, made mainly through qualitative interviews, reports that the country is experiencing more erratic rainfall in what used to be the traditional rainy season (March to May/June), with the result that droughts are more frequent and crop yields and plant varieties are decreasing. By contrast, rains in the short rainy season (October to December) have become more intense and devastating, often being the cause of floods, landslides and soil erosion (Magrath, 2008: 1). Even in the best case in which the quantity of millimeters of rain is

[27] EM-DAT contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. It is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. This database contains information about disasters in the world that satisfy at least one of the following criteria: 10 or more people reported killed, 100 or more people reported affected, declaration of a state of emergency or call for international assistance. Earthquakes, floods, droughts, extreme temperature events and landslides are some of the phenomena recorded in the sample.

the same during the rainy and dry seasons, the distribution of the rain is concentrated in fewer days, shortening the rainy season (Magrath, 2008: 3). Moreover, during the latest twenty years there has been an increase in the average monthly temperatures.

The claims in the Oxfam report are partially supported by Mubiru *et al.* (2012). The authors analyzed historical data about daily rainfall and temperatures and find that there is high variability of the onsets of rainfalls across the country. However, the withdrawal dates remained quite stable, resulting in a shortening of the growing season. The March to May rainy season seems the most affected by variability both in the quantity and distribution of rainfall while the October to December rainy season seems to be stable for the distribution of rains (stable number of rainy days) but with an increasing trend in the amount of rain received. The pattern of rainfall seems on average stable during the dry seasons but the frequency of unusual events within both the dry and rainy seasons has increased (Mubiru et al., 2012; Jennings and Magrath, 2009). Parallel to changes in rainfall patterns, maximum and minimum temperatures changed across the country causing warmer days and nights (Mubiru et al., 2012). The northern and north-east part have been so far the warmest part of the country but the regions that are experiencing higher increases in the temperatures are those in the south-west side, accounting for an increase of about 0.3°C per decade (NAPA, 2007).

Table 3.7 shows the level of weather variables for the survey years in the first season preceding the interview and their respective long-term means calculated in the period 1960-1990 for rainfall and number of rainy days and 1980-2010 for temperatures to exclude (from the long-term means) the effects of more recent climate change in the country (Skoufias et al., 2011).

Table 3.7 Descriptive statistics of weather indicators: long-term means and levels in 2005/06 and 2009/10 for the first season preceding the interview.

Weather variable	Season	N	Long-term mean Mean	Long-term mean St.D.	2005/06 Mean	2005/06 St.D.	2009/10 Mean	2009/10 St.D.
Rainfall mm	Dry 1	58	48.64	21.87	39.29	23.34	108.71	24.15
	Rainy 1	262	147.31	37.56	150.88	44.18	152.79	46.59
	Dry 2	168	87.64	41.56	98.10	36.64	66.75	38.02
No. rainy days	Dry 1	58	4.64	2.10	3.88	2.14	8.16	2.23
	Rainy 1	262	11.75	2.20	12.31	2.56	11.97	1.56
	Dry 2	168	7.19	3.04	7.88	2.32	5.93	2.72
Max temp. (°C)	Dry 1	58	30.24	2.63	31.35	2.71	29.91	2.77
	Rainy 1	262	28.85	2.08	29.17	1.98	29.24	2.04
	Dry 2	168	27.36	0.98	28.28	1.54	28.86	1.07
Min temp. (°C)	Dry 1	58	16	2.55	17.53	1.92	17.19	2.04
	Rainy 1	262	17.29	2.09	19.15	3.56	18.02	1.75
	Dry 2	168	16.21	1.32	17.14	1.15	17.16	0.92

Source: Author's elaborations from UDOM (2012) weather data.

Note: Long-term means are calculated as average weather indicator in the season considered in the period 1960-1990 for rainfall millimeters and number of rainy days and 1980-2000 for maximum and minimum temperatures.

Table 3.8 presents weather variables in terms of deviations from their long-term means to allow for a better understanding of the extent of weather variability. Clearly temperatures data are in line with the findings of the studies aforementioned: on average in Uganda minimum temperatures were from 6 to 11% (about 1 to 2 Celsius degrees) higher in 2005/06 and 5 to 8% higher (0.8 to 1.3 Celsius degrees higher) in 2009/10. Maximum temperatures show a similar increasing pattern, although smaller in magnitude. When considering the average deviations in the same season in the overall period within the two rounds of the survey, again temperatures show sensible increases (except for maximum temperatures in the second dry season for which the higher standard deviation suggest however the occurrence of specific unusual events). On the other hand, rainfall and number of rainy days for the surveyed households show some differences depending on the period considered. During the first rainy season (March to May) and the dry seasons average rainfall and number of rainy days for the overall period within the survey mimic the findings of Mubiru et al (2012) both for rainy and dry seasons. In contrast, when considering data in the previous season for specific survey years rainfall (number of rainy days) data for the first rainy season were 3% (3 to 6.5%) above average while data for the dry seasons vary from negative to positive variations (or vice versa). These descriptive statistics actually help to clarify two levels of weather variations: trend variations and shorter-term (season- and year-specific) variability.

Table 3.8 Descriptive statistics of weather indicators between 2005 and 2010: weather indicators relative to the long term mean, reported as a percentage deviation for the first previous season and period average.

Weather variable	Season	N	2005/06		2009/10		2006/07-2009/10	
			Mean	St.D.	Mean	St.D.	Mean	St.D.
Rainfall mm	Dry 1	58	-18.74	31.00	159.65	92.21	29.34	17.35
	Rainy 1	262	3.04	18.70	2.98	15.64	-7.39	6.82
	Dry 2	168	21.02	34.42	-27.05	19.96	14.52	22.90
No. rainy days	Dry 1	58	-10.32	36.38	91.12	38.41	40.15	33.92
	Rainy 1	262	6.52	21.30	3.40	10.74	-1.57	12.49
	Dry 2	168	18.66	25.79	-19.28	10.73	17.79	18.33
Max temp. (°C)	Dry 1	58	3.71	2.39	-1.05	3.75	0.14	1.70
	Rainy 1	262	1.17	2.88	1.39	2.29	1.17	1.80
	Dry 2	168	3.42	5.10	5.51	2.13	-4.24	10.32
Min temp. (°C)	Dry 1	58	10.94	12.48	8.27	6.50	8.74	9.59
	Rainy 1	262	10.97	15.76	4.80	6.37	3.75	6.80
	Dry 2	168	6.07	6.59	6.26	6.71	4.92	6.93

Source: Author's elaborations based on UDOM (2012) weather data.

Note: Weather indicators assigned to households based on proximity to synoptic station. The reported data are relative to the long-term mean, expressed as percentage deviation. Yearly indicators are the percentage deviations in the season preceding the interview, as reported in the second column. The five years indicators are the percentage deviations of the average indicator in the period, relative to the long term mean. The long-term mean for every indicator is based on all available observations of the relevant synoptic station in the period 1960-1990 for rainfalls and number of rainy days and 1980-2000 for maximum and minimum temperatures. For example, in the whole sample, rainfall in 2005/2006 was 19% lower than the long term mean.

3.4 Data and empirical model

3.4.1 Data

The theoretical framework illustrated in Section 3.2 clearly suggest that the analysis of the impact of weather variability should start with the analysis of the agricultural productivity in first place, agricultural income in second place and finally household consumption. However, I cannot incorporate the production side in the empirical analysis because of a mismatch between the reference period in the household and agricultural questionnaire. The household questionnaire was conducted across two years, asking for a seven days (or month/year depending on the type of goods considered) recall of consumption expenditures, while the data on the agricultural production were collected taking as reference two specific agricultural seasons for all the households so that I am not able to assign to households data exactly the production data of the season preceding the interviews. For instance, in the second round some households completed the household questionnaire in July 2010 (during the second dry season running from June to August 2010) hence, to conduct a step-by-step analysis of production, income and consumption I should consider for these households agricultural production data in the first agricultural season 2010 (running from December to May, 2010). However, the agricultural questionnaire of the 2009/10 round collected data on agricultural production (inputs and outputs) in the two agricultural seasons of 2009. The high instability of the pattern of climate does not allow us to assume that data on production and weather in the first agricultural season in 2010 can be a good proxy of the first agricultural season 2009. For this reason, I had to make the hypothesis that food consumption is a proxy of the agricultural productivity and income and directly conduct the analysis of food consumption. However, the subsistence nature of the agricultural activity (see Table 3.3), unreliable means for on-farm storage, and farmers preferences for selling food immediately after harvest at low prices to satisfy cash needs (Kasente et al., 2002; Mpuga, 2010) suggest that in the context analyzed households may produce in each agricultural season just the amount of products enough to cover the current period. Moreover, the importance of food expenditures as the prevailing share of household expenditures (Table 3.9) makes food consumption expenditures a good indicator of household welfare to be analyzed in the case of climatic shocks. So I can directly analyze the effects of weather deviations on the consumption pattern assuming that the impact of weather variability on food consumption is directly connected with the impact on the agricultural production (consistent with the chain of effects displayed in Figure 3.1).

Table 3.9 Consumption expenditures data 2005/06-2009/10.

	Rural Uganda (UBOS-NHS)		488 hh(LSMS)	
	05/06	09/10	05/06	09/10
Household total expenditures[a]	176,600	197,500	174,958	195,560
Per capita total expenditures[a]	33,150	38,200	29,959	30,556
Shares of households expenditures by item groups (%)[b]				
Food, drink and tobacco	50.00	51.00	55.66	52.34
Food			(91)	(91)
Beverages and tobacco			(6)	(5)
Restaurants			(3)	(4)
Non durable			30.75	31.56
Rent, fuel Energy	15.00	15.00	(52)	(50)
Non-durable and personal goods[c]	4.00	5.00	(12)	(9)
Transport and communication	6.00	7.00	(11)	(16)
Health and medical care	8.00	6.00	(23)	(22)
Other services[c]	2.00	3.00	(2)	(3)
Semi durable			11.41	13.82
Clothing and footwear	4.00	3.00	(36)	(30)
Furniture, carpet, furnishing			(9)	(8)
Household appliances and equipment			(5)	(10)
Glass/table ware, utensils			(4)	(3)
Education	8.00	7.00	(42)	(45)
Services not elsewhere specified			(4)	(4)
Non-consumption	3.00	3.50	2.17	2.28
Outgoing remittances, gifts and other transfers			(47)	(46)
Funerals and other social functions			(36)	(43)
Other (taxes, pensions, subscriptions, interests)			(17)	(11)

Source: Author's elaborations on UBOS-NHS (National Households survey) and LSMS Uganda household panel 2005/06-2009/10.

Note: [a] Adjusted for regional inflation, base year 2005. [b] UBOS reported classification is slightly different from the more detailed breakdown allowed by the data in the LSMS dataset. For the LSMS dataset I report in brackets the shares of expenditures in the four expenditures aggregates by type and durability of items. [c] In UBOS classification Non-durable and personal goods share include semi-durable furniture, households appliances and utensils while Other services includes Services not elsewhere specified

The empirical analysis is conducted combining a household panel dataset with meteorological data from synoptic stations spread across the country. The household panel dataset is made publicly available by the World Bank Living Standard Measurement Study (LSMS) website. The baseline survey comes from the Uganda National Household Survey (UNHS) conducted in 2005/2006. 3,123 households distributed over 322 enumeration areas (EAs) over the 783 EAs visited by the UNHS were selected by the Uganda National Panel Survey (UNPS) to conduct the interviews in 2009/2010. In coherence with the theoretical framework I consider only rural households interviewed in the same season in both rounds to rule out seasonality in consumption, for a total of 488 households. The dataset contains information on the socioeconomic status of the households, with a detailed module on food, non-durable, semi-durable and non-consumption expenditures. Descriptive statistics for the household variables of interest are reported in Table 3.10. Since the food consumption data were collected on the basis of a week recall, I make the variable monthly, correct for inflation (monthly and regional in 2005, and monthly and regional using the base year 2005 for the 2009 data) and I take the logarithm of it.

Table 3.10 Descriptive statistics of selected variables for rural households in Uganda.

	2005/06			2009/10		
Variable	*N*	Mean	St. Dev	*N*	Mean	St. Dev
Month survey	488	8	1.6525	488	8	2.0737
Year survey	488	2005	0	488	2009	0
Sex Head HH[a] (Female=1)	488	0.2275	0.4196	488	0.2520	0.4346
Age Head HH	488	42.6783	15.2597	488	46.8504	15.5713
Education head of the HH						
(1) Don't know	482	0.0000	0.0000	480	0.0042	0.0645
(2) Never attended school	482	0.1784	0.3833	480	0.2063	0.4050
(3) Some schooling but not completed primary	482	0.4502	0.4980	480	0.4479	0.4978
(4) Completed primary	482	0.1701	0.3761	480	0.1438	0.3512
(5) Completed post primary specialization	482	0.0353	0.1847	480	0.0250	0.1563
(6) Completed junior high	482	0.1286	0.3351	480	0.1313	0.3380
(7) Completed secondary	482	0.0062	0.0791	480	0.0104	0.1016
(8) Completed post secondary specialization	482	0.0290	0.1681	480	0.0292	0.1684
(9) Degree or above	482	0.0021	0.0455	480	0.0021	0.0456
Household size	488	5.8443	3.1349	488	6.3996	3.2937
Share of males 0-5	488	0.1224	0.1439	488	0.0994	0.1269
Share of males 6-11	488	0.0823	0.1150	488	0.1022	0.1150
Share of males 12-17	488	0.0728	0.1176	488	0.0917	0.1312
Share of males 18-64	488	0.2125	0.2015	488	0.1911	0.1844
Share of males >65	488	0.0231	0.1150	488	0.0352	0.1398
Share of females 0-5	488	0.0982	0.1375	488	0.0927	0.1254
Share of females 6-11	488	0.0745	0.1033	488	0.0852	0.1091
Share of females 12-17	488	0.0598	0.1028	488	0.0746	0.1148
Share of females 18-64	488	0.2303	0.1749	488	0.2029	0.1383
Share of females >65	488	0.0240	0.1122	488	0.0249	0.0969
Own house (Yes=1)	488	0.8955	0.3062	483	0.9296	0.2561
No. Rooms	488	3.9918	2.3615	483	2.9379	1.6970
Own land (Yes=1)	444	0.8581	0.3493	462	0.9177	0.2750
Owned parcels size (Ha)	446	5.7250	34.7912	474	4.3094	8.3383
HH monthly food consumption[b]	488	86,024.46	66,432.58	484	87,557.27	69,168.5
HH monthly total expenditures	485	174,957.6	175,729.7	484	195,559.8	194.160.4
Region 1 – Central	488	0.2725	0.4457	488	0.2725	0.4457
Region 2 – Eastern	488	0.2459	0.4311	488	0.2459	0.4311
Region 3 – Northern	488	0.2951	0.4565	488	0.2951	0.4565
Region 4 – Western	488	0.1865	0.3899	488	0.1865	0.3899

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel.

Note: [a] HH stands for household. [b] Adjusted for monthly regional inflation. 1 USD=1,780 UGX in 2005.

Weather data come from the Uganda Ministry of Water and Environment - Department of Meteorology (UDOM) daily recordings about precipitation and maximum and minimum temperatures for 13 synoptic stations located throughout the country[28]. Table 3.11 and Map 3.1 show the distribution of the synoptic stations in the country.

Table 3.11 Distribution of synoptic stations across Uganda.

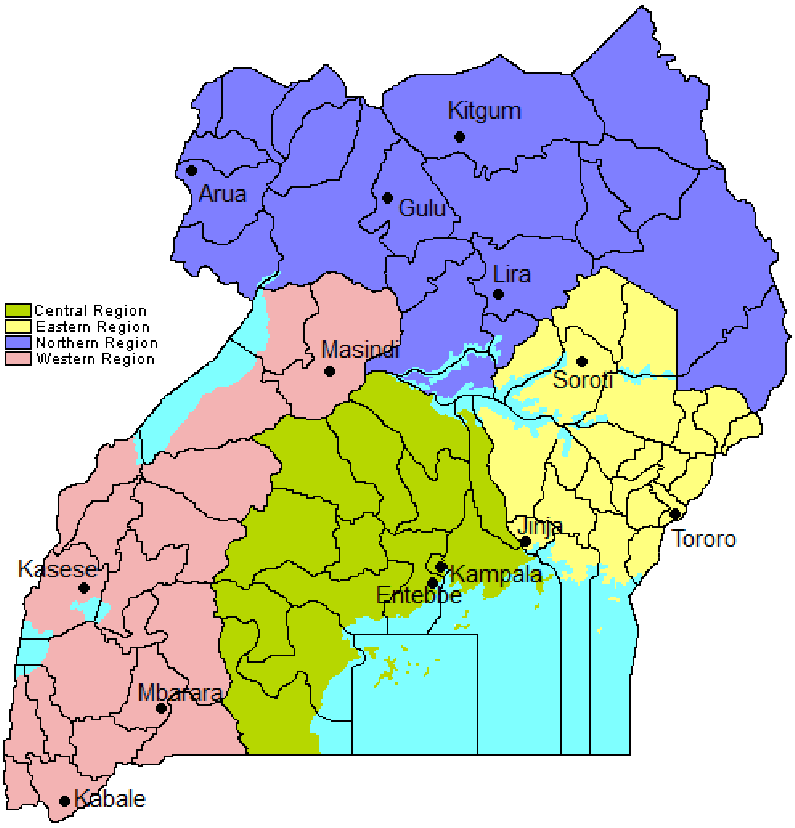
Synoptic Station	Region	Longitude	Latitude	Altitude (meters)	Region Area (sq-Km)
Arua	Northern	30.917	3.05	1280	85,391.7
Gulu		32.283	2.783	1105	
Kitgum		32.883	3.3	940	
Lira		32.933	2.317	1110	
Soroti	Eastern	33.617	1.717	1132	39,478.8
Tororo		34.167	0.683	1170	
Jinja		33.183	0.45	1175	
Kampala	Kampala	32.633	0.25	1200	197.0
Entebbe	Central w/o Kampala	32.45	0.05	1155	61206.3
Mbarara	Western	30.683	-0.6	1420	55,276.5
Masindi		31.717	1.683	1147	
Kasese		30.1	0.183	691	
Kabale		29.983	-1.25	1869	

Source: Author's elaborations based on UDOM (2012) weather data.

Households are assigned data on the synoptic station on the basis of the proximity to the district of residence (the average distance is 32 Km with a standard deviation of 23 Km). From the monthly weather data I calculate the relevant weather variables averaging seasonal levels of rainfall millimeters, number of rainy days and maximum and minimum temperatures for the two seasons preceding the season of interview. Hence, I assign two rainfall and temperature variables for each household, one pertaining to the previous season and one pertaining to the second season back in time.

[28] I preferred national data to NASA data because the width of the NASA grid does not allow for more precision.

Map 3.1 Map of Uganda with regions and synoptic stations.



Source: Adapted from http://commons.wikimedia.org/wiki/File:UgandaRegionsLegend.png, accessed 13November 2012.

Households were interviewed in different seasons so they are assigned different rainfall deviations for a total of about 50 observations for every weather indicator in each survey year. In the case the household was interviewed in the second dry season of year *t*, it is assigned firstly the average weather levels calculated in the first rainy season of year *t* and secondly the deviations calculated in the first dry season of *t*, to check for persistence in the weather shocks. This procedure can be made clearer looking to Figure 3.2 and 3.3. For example, a household interviewed in June 2005 is assigned firstly the March-April-May 2005 variables and secondly the December-January-February 2004/05 variables.

Figure 3.2 Agricultural cycle in Uganda.

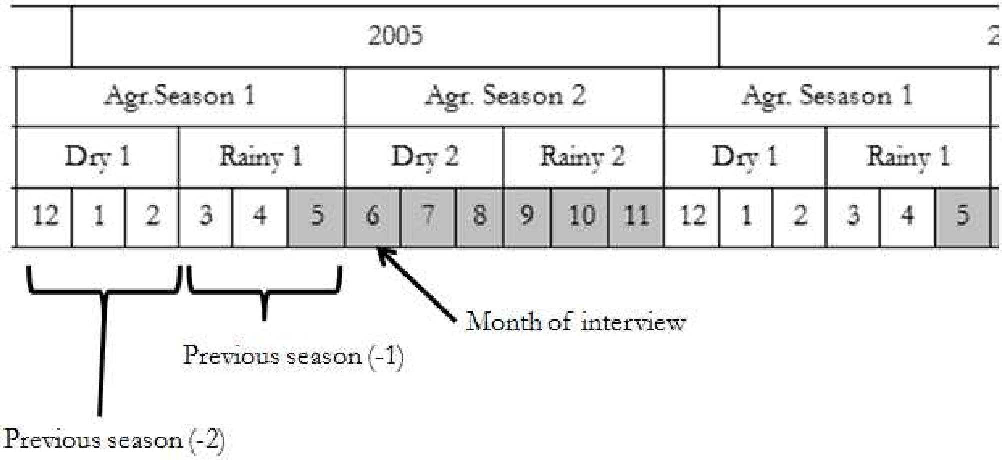
Year	2004							2005												2006										
Agr. Season	Agr. Seas 2						Agr.Season 1						Agr. Season 2						Agr. Sesason 1						Agr. Season 2					
Season	Dry 2			Rainy 2			Dry 1			Rainy 1			Dry 2			Rainy 2			Dry 1			Rainy 1			Dry 2			Rainy 2		
Month	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11

Year		2009												2010												2011				
Agr. Season	Agr. Season 1						Agr. Season 2						Agr. Season 1						Agr. Season 2						Agr. Season 1					
Season	Dry 1			Rainy 1			Dry 2			Rainy 2			Dry 1			Rainy 1			Dry 2			Rainy 2			Dry 1			Rainy 1		
Month	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel and Asiimwe and Mpuga (2007).

Note: In light grey the month in which the interviews were conducted.

Figure 3.3 Example of the mechanism of assignment of weather deviations.



Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel and Asiimwe and Mpuga (2007).

3.4.2 Basic model

The impact of weather variability on household food consumption is analyzed using a panel fixed effect model. For OLS to be unbiased and consistent, the error term has to be uncorrelated with the explanatory variables, hence, the strict exogeneity[29] of weather shocks allows us to obtain good estimates of weather variations effects on food consumption. To avoid the omitted

[29] The strict exogeneity assumption states that $Cov(\Delta X_{it}, \Delta\varepsilon_{it}) = 0$, in other words, that the explanatory variables are independent from the error term across time. In this case, being the weather shocks likely to be random, once I

variables problem (observed and unobserved variables that are correlated with the error term and the weather deviation variables in the explanation of food consumption) I include a vector of household characteristics able to further explain the outcome variable. Similarly, I include a set of variables to take into account unobserved time-invariant factors that can affect food consumption to control for unobserved fixed heterogeneity (Wooldridge, 2009: 456). First, I control for the synoptic station to which households were assigned because, although the prevalent rainfall and temperature is bimodal across the country, there are some small variations in the weather variables depending on the different latitude, longitude and altitude of the area covered by each synoptic station (see Table 3.10). Second, I account for the region in which the household was settled because each region in the country has different specific characteristics due to different regional poverty dynamics (Deininger, 2003; Okurut et al., 2002). Finally I include fixed effects for the season and round of interview to account for seasonality effects of food consumption and other time-invariant characteristics. Results of separate cross-section estimations could be driven by some specific weather shocks occurring in the year considered while pooling the cross sections do not allow us to control for differences across households, hence I exploit the panel nature of the data at hand to control for household specific unobserved characteristics, allowing for more room to infer causality thanks to the availability of more than one observation per household (Wooldridge, 2009: 11). More information and higher efficiency are some advantages of this methodology together with the higher suitability for the study of the dynamics of change in the variable of interest, accounting also for behavioral changes (Gujarati and Porter, 2009: 637). If the unobserved effects were not correlated with the error term, a random effects model would be better in terms of consistency and efficiency of the parameters estimated because loss of some information lowers efficiency in the case of fixed effects models. However random effects estimation with clustered standard errors uses the additional orthogonality conditions that the group means are uncorrelated with the idiosyncratic error. Since clusters are of different size and comprehensive of households settled in different regions with different poverty patterns, the additional orthogonality condition is likely to be violated. Testing for over identifying restrictions using the artificial regression approach of Wooldridge (2002: 290-91) to account for heteroskedastic- and cluster-robust standard errors confirms to use fixed effects estimations (p-value 0.000). The model estimated is the following

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control for them, there should be no correlation of these variables with the error term, then the hypothesis holds and the OLS estimates should be unbiased and consistent.

$$lnFCE_{h,s,r,\mathrm{p},t} = \alpha + \beta lnWV_{h,s,r,p,t-1} + \gamma X_{h,s,r,p,t} + \mu_s + \pi_r + \tau_p + \omega_h + \rho_t + \varepsilon_{h,s,r,p,t} \quad (3.1)$$

where $lnFCE_{h,s,r,p,t}$ is the logarithm of the food consumption expenditures for household *h* assigned to the synoptic station s in region *r,* season *p* and year *t,* while $WV_{h,s,r,p,t-1}$ is a vector of variables describing weather conditions in the period preceding the recorded consumption data. The underlying assumption is that in a subsistence rain-fed economy current consumption levels would be directly affected by weather conditions experienced in the (agricultural production) season preceding the interview. Weather conditions are operationalized through four *weather variables*

i) *Precipitation* measured as the logarithm of the average monthly amount of millimeters of rain in the season preceding the interview

ii) R*ainfall distribution* measured as the logarithm of the average monthly number of rainy days in the season preceding the interview

iii) *Maximum temperature* measured as the logarithm of the average monthly maximum temperature in the season preceding the interview

iv) *Minimum temperature* measured as the logarithm of the average monthly maximum temperature in the season preceding the interview.

$X_{h,s,r,p,t}$ is a vector of household specific characteristics including sex, age, age squared, and education of the head of the household, the size and demographic composition of the household, ownership of house and land (size and number of parcels). μ_s, π_r, τ_p, ω_h and ρ_t are the synoptic station, region, season, household and time dummies while $\varepsilon_{h,s,r,p,t}$ is the error term.

This model is expected to have consistent estimates of the effects of weather variability on food consumption, provided that the unobserved time-invariant fixed characteristics are not correlated to the idiosyncratic error. If weather variations have negative effects on food consumption, β should be positive and significant for rainfall variables and negative and significant for temperatures variables.

3.4.3 Persistency

The work of Dercon (2004) on shocks in Ethiopia and the relationship between the subsistence nature of the agricultural activity suggest investigating the persistency of weather deviation effects. Then, I estimate equation (3.1) adding the persistency term $WV_{h,s,r,p,t-2}$ accounting for the weather variable level in the second season preceding the date of interview

$$lnFCE_{h,s,r,p,t} = \alpha + \beta_1 lnWV_{h,s,r,p,t-1} + \beta_2 lnWV_{h,s,r,p,t-2} + \gamma X_{h,s,r,p,t} + \mu_s + \pi_r + \tau_p + \omega_h + \rho_t + \varepsilon_{h,s,r,p,t}. \quad (3.2)$$

If weather variations have persistent negative effects on food consumption, β_2 should be positive and significant for rainfall variables and negative and significant for temperatures variables.

3.4.4 Heterogeneity of impacts

According to Skoufias (2011: 20), the average effect of weather variations on the outcome variable may mask differences of impacts between households with different welfare levels depending on the ownership of crucial asset such as the house where the household lives or land. Hence, I estimate equation (3.1) introducing an interaction term

$$lnFCE_{h,s,r,p,t} = \alpha + \beta_0 WD_{s,r,p,t-1} + \beta_1 (WD_{s,r,p,t-1} \cdot H_{h,s,r,p,t}) + \gamma_1 H_{h,s,r,p,t} + \gamma_2 X_{h,s,r,p,t} + \mu_s + \pi_r + \tau_p + \omega_h + \rho_t + \varepsilon_{h,s,r,p,t} \quad (3.3)$$

$H_{h,s,r,p,t}$ incorporates the specific household features that are important in determining different impacts of weather variations on food consumption. Therefore, β_0 measures the impact of weather variations independently of particular households characteristics while $(\beta_0 + \beta_1)$ measures the combined impact of weather deviations for households with the specific characteristic considered (house or land ownership).

3.5 Results and robustness checks

The results for the impact of weather deviations on food consumption are presented in Tables 3.12-3.13. Positive and significant coefficients for rainfall and number of rainy days variables would suggest that negative variations in these indicators would affect food consumption negatively. Negative and significant coefficients for temperatures suggest that increasing temperatures may decrease food consumption. I present first the impact of rainfall, then the joint impact of rainfall and number of rainy days, after the effects of temperatures variations only and finally the effect of all the weather deviations combined on the outcome variable for weather variations in the first previous season and finally including persistency terms. The control variables for the odd numbered specifications in the tables are sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership and size of the house and a year dummy (taking value one when the year is 2009). The even numbered specifications also include ownership of land (value one when the household owns land) and size of parcels of owned land. Land ownership constitutes a household wealth indicator, hence a possible tool that may compensate adverse weather variations. If the size of the land owned is bigger, the risk could be diversified through cultivation of different crops or crop mixes in different portions of the owned land[30]. I choose to include these variables only after because for them I have some missing observations that could result in biased estimations.

3.5.1 Weather variability and persistency

As reported in table 3.12, on average and controlling for households demographic and economic characteristics rainfall millimeters seem to have positive but insignificant impacts on food consumption. The result is robust to the inclusion of the variables accounting for land ownership and size of the parcels owned but the magnitude of the coefficients of rainfall increases, suggesting that land constitutes a basic insurance asset in case of adverse weather variations. Combining rainfall with number of rainy days brings further evidence that rainfall precipitation and distribution may not affect food consumption. On the other side, temperatures deviations alone seem to adversely affect food consumption always with 1% level of significance. A 5% increase in minimum temperatures would decrease food consumption by more than 3% while the same increase in maximum temperatures would reduce consumption by about 14%. Note that this result seems to be coherent with the understanding of the crops cycle: higher temperatures in a rainy season may prevent the correct development of the crops while the same event during a dry season may dramatically harm the harvest. When temperatures are considered together with rainfall amount and distribution all weather indicator slightly increase in magnitude, but maintaining their sign and level of significance.

Similar results are found when I include the weather deviation related to the second season back in time with respect to the season when the household was interviewed. Only maximum temperatures seem to have persistent effects but the sign is positive suggesting that an increase in temperatures in the second season back in time would increase food consumption while the effect of the same change in the first previous period temperature would have a higher negative impact. Besides the negative impact of raising temperatures, estimations including all weather

[30] It may also be that diversification is brought about by the different location of the parcels in the country. In this case, shocks experienced by the cultivations in every parcels will be different.

[30] Non consumption expenditures are calculated aggregating income tax, property rates (taxes), user fees and charges, local service tax, pensions and social security payments, remittances (including gifts and other transfers), funerals and other social functions, interests on loans and others.

indicators for both periods emphasize the role of rainfall distribution: on average, food consumption seem to decrease by about 3% for a 10% increase in the number of rainy days at conventional levels of significance. This result seems to confirm the description of the interviewee in the Oxfam report (Magrath, 2008): even if on average the millimeters of rain received during the season are the same as they used to be, the problem arises with their distribution. The negative sign of the coefficient for rainy days could be due to some episodes of heavy floods in the country in the years considered (visible in Table 3.8). Analogously, increases in maximum and minimum temperatures may lead to 1-5% decreases in food consumption while again increasing temperatures in the second period before interviews seem to have positive persistent effects.

3.5.2 Heterogeneity of impacts

As argued in the model specification section, the average effect of weather variations on the outcome variable might mask differences of impacts between households with different welfare levels depending on the ownership of crucial assets such as the house or land. Hence, I estimate the model introducing an interaction term to account for the impact of shocks when the household owns the house or land and depending on the size of the land owned. The estimations accounting for land are conducted also following the analysis of the agricultural production where I emphasized an increase of ownership but a decrease in size (and acreage cultivated) of land in the 488 households subsample.

From the results in specifications (17) and (18) it seems that house and land ownership *per se* may not mitigate adverse rainfall variations (F-test rejecting the joint significance of the interaction terms or worse negative effects of weather variations when the F-test does not reject the joint significance). However, when I consider the size of parcels of land owned by the household I find that land may contribute to lower the negative effects of a decrease in rainfall millimeters depending on the size of both the rainfall variation and land owned. For example, a 3% decrease in rainfall may lower food consumption by about 0.20% if the household owns no land, while if the household owns one hectare of land the rainfall deviation may be completely insured. However, if rainfall decreases by 15% the household may need to have at least 13.5 hectares of land to insure its food consumption.

Table 3.12 Econometric results, results, fixed effect estimations. Dependent variable: ln Food Consumption Expenditures.

	Dependent Variable: ln (Food Consumption Expenditures)													
	Rain (-1)	Days(-1)	Max(-1)	Min(-1)	Rain(-2)	Days(-2)	Max(-2)	Min(-2)	Own land	Size land	Const	Rsqr	N	NHH
(1)	0.037										9.726***	0.147	961	488
	(0.060)										(0.524)			
(2)	0.050								0.231**	-0.001	9.156***	0.159	896	472
	(0.060)								(0.093)	(0.001)	(0.569)			
(3)	0.153	-0.193									9.642***	0.151	961	488
	(0.146)	(0.190)									(0.485)			
(4)	0.174	-0.207							0.223**	-0.001	9.03***	0.164	896	472
	(0.154)	(0.194)							(0.096)	(0.001)	(0.556)			
(5)			-2.807***	-0.69***							21.64***	0.173	961	488
			(0.966)	(0.261)							(3.828)			
(6)			-2.761***	-0.743***					0.253***	-0.054	21.10***	0.185	896	472
			(1.008)	(0.275)					(0.092)	(0.001)	(4.047)			
(7)	0.117	-0.277	-3.346***	-0.776***							23.83***	0.181	961	488
	(0.116)	(0.166)	(1.005)	(0.263)							(3.70)			
(8)	0.137	-0.273	-3.117***	-0.793***					0.243***	-0.001	22.43***	0.192	896	472
	(0.125)	(0.177)	(1.011)	(0.298)					(0.094)	(0.001)	(3.865)			
(9)	0.041				-0.026						9.799***	0.148	961	488
	(0.052)				(0.044)						(0.606)			
(10)	0.052				-0.026				0.224***	-0.001	9.24***	0.160	896	472
	(0.055)				(0.048)				(0.088)	(0.001)	(0.64)			
(11)	0.171	-0.219			0.051	-0.152					9.715	0.156	961	488
	(0.138)	(0.190)			(0.082)	(0.121)					(0.530)			
(12)	0.195	-0.240			0.049	-0.157			0.217***	-0.001	9.128***	0.169	896	472
	(0.142)	(0.189)			(0.090)	(0.122)			(0.083)	(0.001)	(0.576)			
(13)			-3.883***	-0.797***			1.884***	-0.100			19.51***	0.180	961	488
			(0.877)	(0.245)			(0.629)	(0.772)			(5.02)			
(14)			-3.887***	-0.836***			1.990***	-0.348	0.265***	-0.001	19.51***	0.194	896	472
			(0.996)	(0.226)			(0.667)	(0.746)	(0.090)	(0.001)	(5.36)			
(15)	0.103	-0.322***	-5.061***	-1.283***	-0.091	0.023	2.134**	-0.005			24.42***	0.198	961	488
	(0.107)	(0.122)	(0.864)	(0.450)	(0.107)	(0.130)	(1.049)	(0.903)			(6.77)			
(16)	0.138	-0.328***	-4.678***	-1.306***	-0.105	0.027	2.166*	-0.387	0.237***	-0.001	23.56***	0.211	896	472
	(0.109)	(0.125)	(0.971)	(0.512)	(0.118)	(0.133)	(1.107)	(0.914)	(0.087)	(0.001)	(6.62)			

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

Note: The control variables included in the odd numbered specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, year dummy. The even numbered specifications include also the number and size of the owned parcels of land. variables are calculated as natural logarithm of the weather indicator (level) in the first season preceding the interview (-1) or in the second previous season (-2). Robust standard errors clustered by synoptic stations in parenthesis. *, **, *** stand for level of significance at 10, 5 and 1% respectively.

Table 3.13 Econometric results, fixed effect estimations clustered by synoptic station. Dep. var.: ln food consumption expenditures. Heterogeneity of impacts.

Dependent variable: ln (Food Consumption Expenditures)

House		Own House	Rain(-1)	Days(-1)	MaxT(-1)	MinT(-1)	RainxHouse	DaysxHouse	MaxTXHouse	MinTXHouse	Const	Rsqr	Ftest Rain	Ftest Days	Ftest maxt	Ftest mint
(17)		-0.481	-0.037				0.088				9.57***	0.160	0.707			
		(1.408)	(0.306)				(0.310)				(1.59)					
(18)		0.448	0.539	-0.776			-0.383	0.596			8.48***	0.166	0.448	0.303		
		(1.748)	(0.576)	(0.575)			(0.587)	(0.614)			(1.94)					
(19)		-3.699			-2.678	-2.081			-0.076	1.350	24.66**	0.186			0.049	0.042
		(9.783)			(1.554)	(1.936)			(1.534)	(1.985)	(9.67)					
(20)		-6.695	0.606	-0.858	-4.035	-2.265	-0.483	0.599	0.994	1.480	28.75**	0.196	0.477	0.197	0.031	0.061
		(11.397)	(0.623)	(0.602)	(3.408)	(2.776)	(0.615)	(0.621)	(3.015)	(2.750)	(12.10)					

Own Land	Own land	Size land	Rain(-1)	Days(-1)	MaxT(-1)	MinT(-1)	RainxLand	DaysxLand	MaxTXLand	MinTXLand	Const	Rsqr	Ftest Rain	Ftest Days	Ftest maxt	Ftest mint
(21)	0.615	-0.001	0.126				-0.083				8.76***	0.160	0.350			
	(0.461)	(0.001)	(0.086)				(0.095)				(0.723)					
(22)	-0.053	-0.001	-0.141	0.346			0.347	-0.610			9.166	0.167	0.417	0.242		
	(0.871)	(0.001)	(0.331)	(0.387)			(0.359)	(0.395)			(0.950)					
(23)	-2.206	-0.001			-3.844**	-0.200			1.199	-0.542	23.11***	0.186			0.051	0.005
	(5.062)	(0.001)			(1.73)	(0.919)			(1.433)	(0.721)	(7.00)					
(24)	-2.45	-0.001	-0.134	0.171	-3.886**	-0.548	0.302	-0.491	0.898	-0.224	24.46***	0.196	0.409	0.165		
	(5.29)	(0.001)	(0.257)	(0.315)	(1.851)	(0.881)	(0.289)	(0.323)	(1.454)	(0.653)	(7.266)					

Land size	Own Land	Size land	Rain(-1)	Days(-1)	MaxT(-1)	MinT(-1)	RainxSize	DaysxSize	MaxTXSize	MinTXSize	Const	Rsqr	Ftest Rain	Ftest Days	Ftest maxt	Ftest mint
(25)	0.239**	0.013***	0.068				-0.003***				9.076***	0.167	0.000			
	(0.094)	(0.001)	(0.063)				(0.001)				(0.57)					
(25)	0.231**	0.013	0.195	-0.212			-0.003	0.0001			8.94***	0.171	0.518	0.562		
	(0.096)	(0.027)	(0.170)	(0.203)			(0.011)	(0.010)			(0.60)					
(27)	0.265***	-0.116			-3.024***	-0.284*			0.070***	-0.043***	21.32***	0.193			0.005	0.000
	(0.093)	(0.067)			(1.064)	(0.284)			(0.018)	(0.008)	(4.20)					
(28)	0.26***	-0.146	0.137	-0.271	-3.373***	-0.642*	0.002	-0.011	0.065***	-0.028	22.85***	0.201	0.490	0.284	0.003	0.010
	(0.095)	(0.099)	(0.133)	(0.178)	(1.048)	(0.337)	(0.011)	(0.011)	(0.016)	(0.017)	(4.00)					

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

Note: Number of observations is 896 and number of households is 472 for all specifications. The control variables included in the specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, land ownership and size of land, year dummy. Weather variables (-1) are calculated as natural logarithm of the weather indicator in the season preceding the interview. Robust standard errors clustered by synoptic stations in parenthesis. *, **, *** stand for level of significance at 10, 5 and 1% respectively.

3.5.3 Robustness checks

I tested the effects of rainfall variations replicating specification (1)-(8) using as dependent variables the consumption of non-durable, semi-durable and non-consumption expenditures to check if households may lower other expenditures to maintain food consumption. I report in Table 3.14 and 3.15 estimates for expenditures for outgoing remittances and funerals and social functions expenditures (together constitute more than 80% of household non-consumption expenditures). Other estimations are available upon request.

Remittances, gifts and transfers from the household seem to be very responsive to variations in precipitations: on average, a 10% reduction in millimeters of rain would account for more than 20% decrease of outgoing transfers. Moreover, tests to assess correlation between household engagement in secondary activities and weather variations did not suggest increasing labor activity as a complementary coping strategy. Finally, estimations on the overall rural household panel controlling for the season of interview confirm on average the results presented for the 488 household sub-sample.

Table 3.14 Econometric results, fixed effect estimations. Outgoing remittances, gifts and other transfers.

	Dependent variable: ln (Remittances, gifts and other transfers)									
	Rain (-1)	Days (-1)	Max t(-1)	Min t.(-1)	Ownland	Landsize	Const	Rsqr	N	NH
(29)	2.028***						-21.33***	0.141	961	488
	(0.363)						(4.069)			
(30)	2.044***				1.214	-0.014***	-27.65***	0.152	896	472
	(0.350)				(0.920)	(0.003)	(5.011)			
(31)	2.620***	-0.989					-21.76***	0.143	961	488
	(0.909)	(1.158)					(4.24)			
(32)	2.644***	-1.003			1.173	-0.013***	-28.26***	0.154	896	472
	(1.022)	(1.261)			(0.931)	(0.004)	(5.48)			
(33)			-12.592	-10.57**			62.507	0.125	961	488
			(14.114)	(4.278)			(36.51)			
(34)			-14.417	-10.65**	1.500	-0.015***	63.048	0.136	896	472
			(15.067)	(4.307)	(0.985)	(0.004)	(40.880)			
(35)	2.486***	-1.156	-1.968	-8.573***			11.921	0.164	961	488
	(0.943)	(1.153)	(10.988)	(2.582)			(32.904)			
(36)	2.477**	-1.172	-4.090	-8.702***	1.424	-0.014***	13.343	0.176	896	472
	(1.054)	(1.212)	(11.471)	(2.676)	(0.892)	(0.003)	(36.013)			

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

Note: The control variables included in the odd numbered specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, year dummy. The even numbered specifications include also the number and size of the owned parcels of land. variables are calculated as natural logarithm of the weather indicator (level) in the first season preceding the interview (-1) or in the second previous season (-2). Robust standard errors clustered by synoptic stations in parenthesis. *, **, *** stand for level of significance at 10, 5 and 1% respectively.

Table 3.15 Econometric results, fixed effect estimations. Other expenditures.

	Dependent variable: ln(Funerals and other social functions)									
	Rain (-1)	Days (-1)	Max t.(-1)	Min t.(-1)	Ownland	Landsize	Const	Rsqr	N	NH
(37)	0.524**						-1.773	0.066	961	488
	(0.210)						(2.382)			
(38)	0.432				1.064*	-0.432**	-4.434	0.081	896	472
	(0.254)				(0.534)	(0.005)	(2.542)			
(39)	1.341	-1.364					-2.37		961	488
	(0.853)	(1.369)					(2.64)			
(40)	1.034	-1.005			1.023*	-0.011**	-5.044	0.084	896	472
	(0.933)	(1.375)			(0.516)	(0.005)	(2.968)			
(41)			-3.127	-1.984			17.19	0.063	961	488
			(6.618)	(3.706)			(17.97)			
(42)			-0.442	-2.046	1.119**	-0.012**	5.178	0.080	896	472
			(6.751)	(3.884)	(0.537)	(0.005)	(17.867)			
(43)	1.310	-1.415	-1.284	-1.58			7.078	0.071	961	488
	(0.845)	(1.274)	(6.696)	(3.478)			(22.27)			
(44)	1.020	-0.995	1.529	-1.634	1.073**	-0.011**	-5.272	0.085	896	472
	(0.934)	(1.405)	(6.725)	(3.671)	(0.518)	(0.005)	(22.293)			

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

Note: The control variables included in the odd numbered specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, year dummy. The even numbered specifications include also the number and size of the owned parcels of land. variables are calculated as natural logarithm of the weather indicator (level) in the first season preceding the interview (-1) or in the second previous season (-2). Robust standard errors clustered by synoptic stations in parenthesis. *, **, *** stand for level of significance at 10, 5 and 1% respectively.

3.6 Triangulation of the results

In this Chapter I focused on the impact of simple extreme events on food consumption highlighting the channels through which rural households in developing countries could be affected. I applied the framework to the context of Uganda where two key changes were revealed by studies on weather and climate patterns: increased variability in rainfall and number of rainy days and increase in temperatures. Hence, I studied the impact of weather variability on food consumption matching a subsample of the World Bank LSMS panel dataset 2005/06-2009/10 with UDOM weather data concerning rainfall millimeters, number of rainy days and minimum and maximum temperatures. The empirical analysis suggests two main results. First, on average temperature increases would have significant negative effects on food consumption in Uganda. This result is particularly relevant because it emphasizes the need to protect household food security from current and future warming. Second, generally changes in the amount and distribution of precipitations seem to leave food consumption unaffected. Given that the agricultural activity in Uganda is mostly rain-fed, this latter result suggests that households might be engaged into a successful set of *ex-ante* and *ex-post* coping strategies to counteract adverse rainfall variations.

Ex-ante, there is evidence that households gradually changed the crops cultivated to preserve food consumption from increasing adverse variation in precipitations. In Section 3.3.1 I presented data on the agricultural production for major food and cash crops cultivated in the country. The data show sharp increases in the cultivation of major staples (maize, beans, cassava), while high-income, high-risk cash crops such as coffee, tea or tobacco have been experiencing decreasing or only minor increases in land cultivated. This argument is further supported by the findings of the qualitative studies by Magrath (2008), Okonya et al., (2013) and Osbahr et al. (2011).

As already mentioned in Section 3.2.2 interviews with farmers' representatives by Magrath (2008) emphasized that

> "[due to] the shortened rains [farmers] have to go for early maturing varieties and now people are trying to select these. That's why some local varieties of pumpkins and cassava that need a lot of rain, even varieties of beans, have disappeared."

Okonya et al. (2013) conducted a survey in six agro-ecological zones of Uganda assessing also farmers' changes on their farms to counteract climatic change in the last ten years. About 45% of the households reported starting to plant trees to commercialize fruit and charcoal/firewood and improve soil fertility. About 35% of the households reported starting to plant quick-maturing crop varieties, while about 25% of the households reported starting to plant new/high yielding varieties and/or drought-tolerant crops/varieties. Similarly, Osbahr et al. (2011: 310) report farmers' perceptions of changing climate and their change in crops cultivated

> "Now farmers are having to use the swampy areas as fields [partly due to land pressure] but in a dry year even the wells are drying up due to inadequate rains [impact on groundwater] so we have changed to resistant cassava and beans with soil and water conservation methods."

As for coffee, the traditional cash crop produced in Southern Uganda and highly affected by dry spells, Magrath (2008) reveals that farmers are adopting several measures

> "In particular, [farmers] are growing more trees around the coffee bushes to provide shade; conserving soil moisture and preventing soil from drying out and cracking by mulching; and conserving and reusing water through measures such as terracing. UCDA has started promoting agro-forestry and has seen very good results in mid-northern areas such as Gulu, according to Edward Lutaakome- Sentamu, Principal Development Officer of the UCDA."

Moreover, the size of land owned seems to partially insure household from rainfall variations. While land can be considered an indicator of wealth, hence of higher ability to insure *ex-post* against shocks, the econometric analysis suggests that mitigation of adverse rainfall events would depend on the size of land owned. This further suggests that households with bigger parcels might have adopted crop diversification strategies combining crops with different levels of resistance to excess/scarce water, while bigger parcels can be used as collateral to obtain credit and finance investments to improve land use (soil and conservation methods).

Ex-post, there is evidence that households try to preserve food consumption from adverse rainfall variations through the reduction of other expenditures. In particular, outgoing remittances and social function expenditures seem to absorb a considerable part of adverse rainfall variations.

3.7 Conclusions

The analysis of the effects of weather variability on household food consumption in Uganda has emphasized that simple natural extreme events may have different effects on households welfare depending on the specific event considered and the coping strategies adopted. Farming requires constant climate-risk management. The findings of the analysis suggest successful engagement of households in informal risk management strategies for rainfall variations. However, the informal risk management strategies adopted by households in Uganda may also be source of efficiency losses and poverty traps. Income stabilization should also provide means to pursue development and income growth for households in Uganda, hence focusing on the production of staples may not be a sustainable strategy to counteract adverse effects of weather variability while sustaining income growth in the long-term. Moreover, informal risk management in Uganda does not seem to be able to insure households against temperature variations. Temperatures average scenarios simulations (1 to 2.8°C increases) for Uganda for the prevalent humid-sub humid system show 4.6% reduction in maize production and 3.7% reduction in bean production to 2030 (Thornton, 2010). Therefore, the increasing need to put in place further coping and adaptation measures. Formal public and private risk management strategies, such as the ones adopted by high income countries or emerging countries like Mexico and India could serve both to evade poverty traps stabilizing income and fostering adaptation (World Bank, 2005). For example, in Canada, Mexico and South Africa, risk insurance contracts have become popular strategies to manage weather-related risks (Hess et al., 2003), while in India monsoon-indexed lending and insurance for small holders covers now more than 9 million farmers (Clarke et al., 2012). A discussion of formal market mechanisms is reported in Chapter 5.

References

Anderson, C. (1994) 'The Aggregate Excess Measure of Severity of Extreme Events', *Journal of Research of the National Institute of Standards and Technology* 99 (4): 555-561.

Asiimwe, J.B. and P. Mpuga (2007) *Implications of Rainfall Shocks for Household Income and Consumption in Uganda*. Nairobi: African economic research consortium (AERC).

Bagamba, F., K. Burger, and W.K. Tushemereirwe (2008) 'Banana (Musa spp.) Production Characteristics and Performance in Uganda', International Conference on Banana and Plantain in Africa. Accessed 1 May 2013 <http://www.actahort.org/books/879/879_17.htm>.

Bardhan, P.K. and C. Udry (1999) *Development Microeconomics*. Oxford [etc.]: Oxford University Press.

Barnwal, P. and K. Kotani (2013) 'Climatic impacts across agricultural crop yield distributions: An application of quintile regression on rice crops in Andhra Pradesh, India', Ecological Economics 87 (3): 95-109.

Benin, S., E. Nkonya, G. Okecho, J. Pender, S. Nahdy and S. Mugarura (2007) 'Assessing the Impact of the National Agricultural Advisory Services (NAADS) in the Uganda Rural Livelihoods', *IFPRI Discussion Paper No. 724*. Washington, DC: IFPRI.

Benson, T., S. Mugarura and K. Wanda (2008) 'Impacts in Uganda of Rising Global Food Prices: The Role of Diversified Staples and Limited Price Transmission', *Agricultural Economics* 39 (s1): 513-524.

Betz, M. (2009) 'The Effectiveness of Agricultural Extension With Respect to Farm Size: The Case of Uganda', paper presented at the Agricultural and Applied Economics Association and ACCI Annual Meeting, 26-29 July, Milwaukee, Wisconsin.

Clarke, D., O. Mahul, K.N. Rao and N. Verma (2012) 'Weather based crop insurance', *World Bank Policy Research Working Paper* 5985. Washington, DC: The World Bank.

Cooper, P., J. Dimes, K. Rao, B. Shapiro, B. Shiferaw and S. Twomlow (2008) 'Coping Better with Current Climatic Variability in the Rain-Fed Farming Systems of Sub-Saharan Africa: An Essential First Step in Adapting to Future Climate Change?', *Agriculture, Ecosystems and Environment* 126 (1): 24-35.

Deininger, K. (2003) 'Causes and Consequences of Civil Strife: Micro□level Evidence from Uganda', *Oxford Economic Papers* 55 (4): 579-606.

Dercon, S. (1996) 'Risk, Crop Choice, and Savings: Evidence from Tanzania', *Economic Development and Cultural Change* 44(3): 485-513.

Dercon, S. (2004) 'Growth and Shocks: Evidence from Rural Ethiopia', *Journal of Development Economics* 74 (2): 309-329.

Dercon, S., J. Hoddinott and T. Woldehanna (2005) 'Shocks and Consumption in 15 Ethiopian Villages, 1999-2004', *Journal of African Economies* 14 (4): 559.

Deressa, T.T. (2007) 'Measuring the Economic Impact of Climate Change on Ethiopian Agriculture: Ricardian Approach', *World Bank Policy Research Working Paper* 4342. Washington, DC: World Bank.

Deschênes, O. and M. Greenstone (2007) 'The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather', *The American Economic Review* 97 (1): 354-385.

Di Falco, S., M. Yesuf, G. Kohlin and C. Ringler (2012) 'Estimating the Impact of Climate Change on Agriculture in Low-Income Countries: Household Level Evidence from the Nile Basin, Ethiopia', *Environmental and Resource Economics* 52 (4): 457-478.

Duflo, E. and C. Udry (2004) 'Intrahousehold Resource Allocation in Cote d'Ivoire: Social Norms, Separate Accounts and Consumption Choices', *NBER Working Paper* 10498. Cambridge, MA: NBER.

EM-DAT (last update 2012) *The OFDA/CRED International Disaster Database.* Brussels, Belgium: Université Catholique de Louvain. Accessed 16 June 2012 <www.emdat.be >.

Ersado, L. (2005) 'Income diversification before and after economic shocks: evidence from urban and rural Zimbabwe', *Development Southern Africa* 22 (1): 27-45.

Ersado, L., H. Alderman and J. Alwang (2003) 'Changes in consumption and saving behavior before and after economic shocks: Evidence from Zimbabwe', *Economic Development and Cultural Change* 52 (1): 187-215.

Fafchamps, M. and S. Lund (2003) 'Risk-sharing networks in rural Philippines', *Journal of Development Economics* 71 (2): 26-287.

Fafchamps, M., C. Udry and K. Czukas (1998) 'Drought and saving in West Africa: are livestock a buffer stock?', *Jounal of Development Economics* 55 (2): 273-305.

FAO (Last updated 2012). FAOSTAT Database (a webpage of FAO). Accessed 15th October 2012 <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>.

Foster, A.D. and M.R. Rosenzweig (1995) 'Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture', *Journal of political Economy* 103 (6): 1176-1209.

Gujarati, D.N. and Porter, D.C. (2009). *Basic Econometrics. Fifth Edition.* Boston [etc.]: McGraw Hill.

Hess, Ulrich (2003) 'Innovative financial services for rural India', *Agriculture and Rural Development Working Paper* 9. Washington, DC: The World Bank, Agricultural and Rural Development Department.

Hickey, S. (2013) 'Beyond the Poverty Agenda? Insights from the New Politics of Development in Uganda', *World Development* 43 (3): 194-206.

IPCC (2001) *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press.

ISDR (2009) *Global Assessment Report on Disaster Risk Reduction*. Geneva, Switzerland: United Nations.

Jacoby, H.G. and E. Skoufias (1997) 'Testing theories of consumption behavior using information on aggregate shocks: income seasonality and rainfall in rural India', *American Journal of Agricultural Economics* 80 (1): 1-14.

Jalan, J. and M. Ravallion (1999) 'Are the poor less well insured? Evidence on vulnerability to income risk in rural China', *Journal of Development Economics* 58 (1): 61-81.

James, P.A.S. (2010) 'Using Farmers' Preferences to Assess Development Policy: A Case Study of Uganda', *Development Policy Review* 28 (3): 359-378.

Jennings, S. and J. Magrath (2009) *What Happened to the Seasons?*. UK: Oxfam.

Kabubo-Mariara, J. and F.K. Karanja (2007) 'The economic impact of climate change on Kenyan crop agriculture: a Ricardian approach', *Global and Planetary Change* 57 (3-4): 319-330.

Kasente, D., M. Lockwod, J. Vivian and A. Whitehead (2002) 'Gender and the Expansion of Non-Traditional Agricultural Exports in Uganda', in Razavi, S. (ed.) *Shifting Burdens, Gender and Agrarian Change under Neoliberalism,* 35-65. United Nations Research Institute for Development. Bloomfield: Kumarian Press.

Kazianga, H. and C. Udry (2006) 'Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso', *Journal of Development Economics* 79 (2): 413-446.

Kinsey, B., K. Burger and J.W. Gunning (1998) 'Coping with drought in Zimbabwe: Survey evidence on responses of rural households to risk', *World Development* 26 (1): 89-110.

Kraybill, D. and M. Kidoido (2009) 'Analysis of Relative Profitability of Key Ugandan Agricultural Enterprises by Agricultural Production Zones', *Uganda Strategy Support Program*, background paper USSP 04. Kampala: IFPRI.

Kurukulasuriya, P. and R. Mendelsohn (2008) 'Crop switching as a strategy for adapting to climate change', *African Journal of Agricultural and Resource Economics* 2 (1): 105-126.

Lansigan, F., W. De los Santos and J. Coladilla (2000) 'Agronomic Impacts of Climate Variability on Rice Production in the Philippines', *Agriculture, Ecosystems and Environment* 82 (1): 129-137.

MAAIF (2010) *Agriculture Sector Development Strategy and Investment Plan: 2010/11-2014/15. Agriculture for Food and Income Security*. Kampala, Uganda: MAAIF.

Magrath, J. (2008) *Turning Up the Heat: Climate Change and Poverty in Uganda*. UK: Oxfam.

McSweeney, C., M. New and G. Lizcano (2007) *Uganda - UNDP Climate Change Country Profiles* 27, available at < http://country-profiles.geog.ox.ac.uk>.

Mendelsohn, R., W.D. Nordhaus and D. Shaw (1994) 'The impact of global warming on agriculture: a Ricardian analysis', *The American Economic Review* 84 (4): 753-771.

Minten, B. and C.B. Barrett (2008) 'Agricultural Technology, Productivity, and Poverty in Madagascar', *World Development* 36 (5): 797-822.

Molua, E.L. (2009) 'An empirical assessment of the impact of climate change on smallholder agriculture in Cameroon', *Global and planetary change* 67 (3-4): 205-208.

Morduch, J. (1995) 'Income Smoothing and Consumption Smoothing', *The Journal of Economic Perspectives* 9 (3): 103-114.

Mpuga, P. (2010) 'Constraints in Access to and Demand for Rural Credit: Evidence from Uganda', *African Development Review* 22 (1): 115-148.

Mubiru, D.N., E. Komutunga, A. Agona, A. Apok, T. Ngara, S. Energy (2012) 'Characterizing Agro meteorological Climate Risks and Uncertainties: Crop Production in Uganda', *South African Journal of Science* 108 (3/4), Art. #470, 11 pages. Available at <http:// dx.doi.org/10.4102/sajs. v108i3/4.470>.

Mwerera, R. L., J.G.M. Majaliwa and P. Isubikalu (2010) 'Climate change adaptation strategies among agricultural communities in Uganda: The case of Kabale and Nakasongla districts', Second RUFORUM Biennial Meeting, Kampala, 20-24 September. Entebbe, Uganda.

NAPA (2007) *Uganda National Adaptation Programmes of Action*. Republic of Uganda, Ministry of Environment.

Nordhaus, W.D. (1993) 'Reflections on the Economics of Climate Change', *The Journal of Economic Perspectives* 7 (4): 11-25.

Okonya, J.S., K. Syndikus and J. Kroschel (2013) 'Farmers' perception of and coping strategies to climate change: evidence from six agro-ecological zones of Uganda', *Journal of Agricultural Science* 5 (8): 252-263.

Okori, W., J. Obua and V. Baryamureeba (2009) 'Famine Disaster Causes and Management Based on Local Community's Perception in Northern Uganda', *Research Journal of Social Sciences*, 4: 21□32.

Okoboi, G., A. Kuteesa and M. Barungi (2013) 'The Impact of the National Agricultural Advisory Services Program on Household Production and Welfare in Uganda', *Africa Growth Initiative Working Paper 7* (March). Washington: Brookings.

Okurut, F.N., J.O.O. Odwee and A. Adebua (2002) 'Determinants of Regional Poverty in Uganda', *AERC Research Paper*, No. 122. Nairobi, Kenya: African Economic Research Consortium.

Olasantan, F., H. Ezumah and E. Lucas (1996) 'Effects of Intercropping with Maize on the Micro-Environment, Growth and Yield of Cassava', *Agriculture, Ecosystems and Environment* 57 (2): 149-158.

Osbahr, H., P. Dorward, R. Stern and S. Cooper (2011) 'Supporting agricultural innovation in Uganda to respond to climate risk: linking climate change and variability with farmer perceptions', *Experimental Agriculture* 47 (2): 293-316.

Otegui, M.E., F.H. Andrade and E.E. Suero (1995) 'Growth, Water use, and Kernel Abortion of Maize Subjected to Drought at Silking', *Field Crops Research* 40 (2): 87-94.

Parry, M.L., C. Rosenzweig, A. Iglesias, M. Livermore and G. Fischer (2004) 'Effects of climate change on global food production under SRES emissions and socio-economic scenarios', *Global Environmental Change* 14 (1): 53-67.

Paxson, C.H. (1992) 'Using Weather Variability to Estimate the Response of Savings to Transitory Income in Thailand', *The American Economic Review* 82 (2): 15-33.

Pender, J., E. Nkoya, P. Jagger, D. Sserunkuuma and H. Ssali (2004) 'Strategies to Increase Agricultural Productivity and Reduce Land Degradation: Evidence from Uganda', *Agricultural Economics* 31 (2-3): 181-195.

Prasad, P., S. Pisipati, R. Mutava and M. Tuinstra (2008) 'Sensitivity of Grain Sorghum to High Temperature Stress during Reproductive Development', *Crop Science* 48 (5): 1911-1917.

Reardon, T., P. Matlon and C. Delgado (1988) 'Coping with household-level food insecurity in drought-affected areas of Burkina Faso', World Development 16 (9): 1065-1074.

Reardon, T. and J.E. Taylor (1996) 'Agro climatic Shock, Income Inequality, and Poverty: Evidence from Burkina Faso', *World Development* 24 (5): 901-914.

Rivington, M. and J. Koo (2010) *Report on the meta-analysis of crop modelling for climate change and food security survey*. Copenhagen: Climate Change, Agriculture and Food Security Programme, University of Copenhagen.

Rosenzweig, M. and H. Binswanger (1993) 'Wealth, weather risk and the composition and profitability of agricultural investments', *The Economic Journal* 103 (416): 56-78.

Rosenzweig, C. and M.L. Parry (1994) 'Potential impact of climate change on world food supply', *Nature* 367 (6459): 133-138.

Shively, G. and J. Hao (2012) 'A Review of Agriculture, Food Security and Human Nutrition Issues in Uganda', *Staff Paper* 12. Purdue, IN: Purdue University, Department of Agricultural Economics.

Schlenker, W. and M. Roberts (2008) 'Estimating the impact of climate change on crop yields: The importance of nonlinear temperature effects', *NBER Working Paper* 13799. Cambridge, MA: NBER.

Singh, I., L. Squire and J. Strauss (1986) 'A Survey of Agricultural Household Models: Recent Findings and Policy Implications', *The World Bank Economic Review* 1 (1): 149-179.

Skoufias, E. and A.R. Quisumbing (2005) 'Consumption Insurance and Vulnerability to Poverty: A Synthesis of the Evidence from Bangladesh, Ethiopia, Mali, Mexico and Russia', *The European Journal of Development Research* 17 (1): 24-58.

Skoufias, E. and K. Vinha (2013) 'The impacts of climate variability on household welfare in rural Mexico', *Population and Environment* 34 (3): 370-399.

Skoufias, E., K. Vinha and H. Conroy (2011) 'The Impacts of Climate Variability on Welfare in Rural Mexico', *World Bank Policy Research Working Paper* 5555.

Thomas, T., L. Christiaensen, Q.T. Do and L.D. Trung (2010) 'Natural disasters and household welfare. Evidence from Vietnam', *World Bank Policy Research Working Paper* 5491. Washington, DC: World Bank.

Thornton, P.K., P.G. Jones, G. Alagarswamy and J. Andersen (2009) 'Spatial variation of crop yield response to climate change in East Africa', *Global Environmental Change* 19 (1): 54-65.

Thornton, P.K., P.G. Jones, G. Alagarswamy, J. Andersen and M. Herrero (2010) 'Adapting to climate change: agricultural system and household impacts in East Africa', *Agricultural systems* 103 (2): 73-82.

Tol, R.S.J. (2009) 'The Economic Effects of Climate Change', *The Journal of Economic Perspectives* 23 (2): 29-51.

Townsend, R.M. (1994) 'Risk and insurance in village India', *Econometrica* 62 (3): 539-591.

Tschirley, D. and M.T. Weber (1994) 'Food security strategies under extremely adverse conditions: the determinants of household income and consumption in rural Mozambique', *World Development* 22 (2): 159-173.

UBOS (2010) *The Uganda National Panel Survey 2009/2010. Basic Information Document.* Kampala, Uganda: Uganda Bureau of Statistics.

UDOM (2012) Weather data. Entebbe, Uganda: Department of Meteorology, Ministry of Water and Environment of the Government of Uganda.

Wooldridge, J.M. (2002) *Econometric Analysis of Cross Section and Panel Data*. London, UK: The MIT Press.

Wooldridge, J.M. (2009) *Introductory Econometrics: A Modern Approach.* Mason, OH [etc.]: South-Western/Cengage Learning.

Wopereis, M., M. Kropff, A. Maligaya and T. Tuong (1996) 'Drought-Stress Responses of Two Lowland Rice Cultivars to Soil Water Status', *Field Crops Research* 46 (1): 21-39.

World Bank (2005) *Managing agricultural production risk.* Washington, DC: The World Bank., Agriculture and Rural Development Department.

World Bank (Last updated 2011). *World Bank Database*. Accessed 30 June 2012 <http://data.worldbank.org/country/uganda>.

Appendix B1

Table B.1 Descriptive statistics of weather indicators: long-term means and levels for the second season preceding the interview (-2) in 2005/06 and 2009/10.

Weather variable			Long term means		2005/06		2009/10	
	Season	N	Mean	St.D.	Mean	St.D.	Mean	St.D.
Rainfall mm	Rainy 2	58	140.13	25.81	137.44	44.19	153.64	15.89
	Dry 1	262	54.46	23.10	45.74	24.92	105.41	39.69
	Rainy 1	168	140.18	37.26	138.79	46.86	119.38	46.44
No. rainy days	Rainy 2	58	10.98	1.13	11.40	1.43	12.81	1.03
	Dry 1	262	5.29	2.14	4.32	2.08	8.30	2.10
	Rainy 1	168	11.33	1.96	11.73	2.79	10.93	1.55
Max temp. (°C)	Rainy 2	58	28.48	1.94	28.67	2.14	28.38	1.91
	Dry 1	262	29.91	2.31	31.25	2.49	29.66	2.59
	Rainy 1	168	28.22	1.38	28.91	1.37	28.71	1.52
Min temp. (°C)	Rainy 2	58	15.88	2.35	16.46	2.08	17.03	1.81
	Dry 1	262	16.41	2.21	17.73	1.80	17.47	1.87
	Rainy 1	168	17.29	1.31	18.15	1.14	17.77	1.11

Source: Author's elaborations from UDOM (2012) weather data.

Note: Long-term means are calculated as average weather indicator in the season considered in the period 1960-1990 for rainfall millimeters and number of rainy days and 1980-2000 for maximum and minimum temperatures.

Table B.2 Weather indicators between 2005 and 2010: percentage deviations from long-term means.

Weather variable			2005/06		2009/10		2006/07-2009/10	
	Season	N	Mean	St.D.	Mean	St.D.	Mean	St.D,
Rainfall mm	Rainy 2	58	-2.00	27.06	159.65	92.21	5.63	5.76
	Dry 1	262	-15.84	29.20	2.98	15.64	28.34	19.07
	Rainy 1	168	-1.55	15.77	-27.05	19.96	-11.5	7.46
No. Rainy days	Rainy 2	58	4.14	10.85	91.12	38.41	7.56	16.49
	Dry 1	262	-12.18	36.75	3.40	10.74	33.65	34.62
	Rainy 1	168	3.83	19.07	-19.28	10.73	-2.35	11.86
Max temp.	Rainy 2	58	0.62	1.79	-1.05	3.75	0.07	1.64
	Dry 1	262	4.53	2.65	1.39	2.29	0.33	1.56
	Rainy 1	168	2.56	5.00	5.51	2.13	1.71	2.01
Min temp.	Rainy 2	58	4.31	8.51	8.27	6.50	11.94	14.50
	Dry 1	262	8.93	9.64	4.80	6.37	6.58	8.02
	Rainy 1	168	5.29	6.61	6.26	6.71	2.09	5.91

Source: Author's elaborations based on UDOM (2012) weather data.

Note: Weather indicators assigned to households based on proximity to synoptic station. The reported data are rainfall millimeters, number of rainy days and maximum and minimum temperature in a particular period, relative to the long-term mean, expressed as percentage deviation. Yearly indicators are the percentage deviations in the season preceding the interview, reported in the second column. The four years indicators are the percentage deviations of the average indicator in the period, relative to the long term mean. The long term mean for every indicator, in the season considered is based on all available observations of the relevant synoptic station in the period 1960-1990 for rainfalls and number of rainy days and 1980-2000 for maximum and minimum temperatures.

Chapter 4

Misfortunes never come singly: structural change, shocks and child malnutrition in rural Senegal[31]

Abstract

In this study I consider the impact of drought and increasing prices shocks on child weight-for-age. The analysis is conducted with a multi-shock approach to account for concomitance of adverse events from the natural, biological, economic and health sphere. I use a unique dataset of children reported leaving in poor rural households in eight regions of Senegal in 2009 and 2011. The analysis relies on pooled-cross sections and accounts for structural changes occurring between survey periods. Results of drought (icreasing prices) difference-in-difference econometric analyses show a deterioration in child weight-for-age reaching 50% (20%) of the weight-for-age standard deviation in 2011. However, triple difference estimations accounting for drought and increasing prices concomitance show that weight-for-age for children experiencing both shocks is left unaffected. I argue that this last result is driven by the increase in rural household income and food security in the framework of the agricultural household model.

JEL: O12; Q54; I12.

Keywords: shocks; child weight; Senegal.

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[31] This chapter benefits from comments from Natascha Wagner, professors and phd collegues at the Doctoral School, and participants at the Economics of Development and Emerging Markets seminar at the International Institute of Social Studies.

4.1 Introduction

The proverb "Misfortunes never come singly" claims that adverse events are correlated and develop their full potential due to their joint occurrence. Although the focus of this thesis is on the effects of natural disasters, the proverb reminds us that natural, biological, economic and health shocks are often concomitant. Accounting for multiple shocks is especially relevant when studying the conditions of poor, shock-prone households in developing countries. Multiple shocks and their concomitance further affect the poor people's welfare in terms of income, consumption and health. The existing literature mainly focuses on the effects of a single or limited set of shocks (Yilma et al., 2013), hence with this work I add to the academic discussion on the effects of natural and non-natural shocks adopting a multi-shock framework.

It is difficult to detect the causal impact of adverse events. On the one hand, the likelihood of exposure to shocks may be correlated with unobservable characteristics at the household and individual level (Alderman et al., 2006). Timing and simultaneity of shocks may further increase vulnerability and exposure, worsening the effects of a single exogenous shock. On the other hand, as discussed in Chapter 3 households may adopt a variety of strategies in response to shocks (Heltberg et al., 2012; Murdoch, 1995). There is ample evidence for *ex-ante* diversification strategies (Dercon, 1996; Rosenzweig and Udry, 2013) and *ex-post* behavior-, asset- and assistance-based coping mechanisms (Heltberg and Lund, 2009). Coping strategies may be specifically related to the nature of the shock while mitigating/exacerbating the initial shocks effects (Alderman et al., 2006). Then, especially in shock-prone areas a multi-shock analysis is required to better understand both the size of the shock impact and the household's ability to cope (Wagstaff and Lindelow, 2010). For one, the occurrence of multiple shocks at the same time may worsen household welfare more than a single shock analysis would predict. At the same time, heterogeneity in the type of shocks experienced by the household as a whole and heterogeneity in the role of individuals being particularly affected may be a source of differential net effects at the household and individual level.

Most studies that measure household living standards and the effects of shocks on household welfare rely on consumption and income data. However these data have been found to be particularly sensitive to changes in the survey design across countries and over time. For example, Beegle et al. (2012) analyzed the possible sources of reporting error and revealed considerable differences in recorded consumption depending on method of data collection, respondent level, respondent level of education, length of the reference period and degree of detail in the commodity list. To address the shortcomings of consumption data, Carter and Maluccio (2003) suggest that child anthropometrics for below 5 year are a better measure for consumption smoothing due to the objectivity of the measurement procedure. Using child anthropometric data as measures of health status and household welfare in the context of hazardous events has further advantages. First, children are some of the most vulnerable individuals in poor households in developing countries (Bengtsson, 2010; Hoddinott and Kinsey, 2001; Martorell, 1999). Second, getting exact indicators for child nutritional status is less challenging than getting similar measures for adults. Indeed, when assessing the wellbeing of adults, one needs to jointly account for consumption, productivity and income to allow for the possibility that in times of distresses households allocate scarce resources to adults with a higher marginal product of health and better wages (Dercon and Krishnan, 2000). Third, low child growth affects individual health and working performance in adulthood emphasizing the relevance of short-term analyses also in a long-term perspective (Hoddinott and Kinsey, 2001; Maccini and Yang, 2008).

Therefore, I focus on child weight-for-age to capture wellbeing. Recent works use natural experiments generated by macroeconomic crises (Block et al., 2004; Paxson and Schady, 2005; Pongou et al., 2006), specific natural disasters (Hoddinott and Kinsey, 2001; del Ninno and Lundberg, 2005; Yamano et al., 2005) or commodity price changes (de Braw, 2011; Cogneau and Jedwab, 2012). I add on this literature analyzing the effects of a short-term increase in purchasing prices in rural Senegal conducting a multi-shock analysis accounting for the occurrence of natural hazards (complex extreme events), biological, economic and health shocks on child anthropometric characteristics. A unique dataset of children living in poor households in rural Senegal is employed. The two rounds of the dataset were implemented in 2009 and in 2011 after the second international food price spike (February 2011). The dataset is particularly suitable to conduct a multi-shock analysis since it contains a very rich shock module for vulnerable rural households. Since only few children have repeated observations across survey years I conduct pooled cross-section analysis accounting for village-year fixed effects. After a basic partial shock analysis I consider the effects of two major adverse events (an increase in purchasing prices and droughts) on child weight-for-age while accounting for other natural, biological, economic and health shocks experienced by the children's households. Since major changes occurred in between the survey rounds I use a difference-in-difference estimator accounting for the 2011 structural improvements. Finally I consider the combined effects of the increase in purchasing prices and droughts shocks, while controlling for all other adverse events experienced by the households. First, I show that controlling for more than one shock helps to better quantify the effect of the different adverse events. Second, I show that the fundamental changes in 2011 seemed not enough to insure child health if the respective household experienced higher purchasing prices or a drought. However, if the household experienced both shocks the net effect in 2011 was not significant. I argue that concomitance of the two major shocks considered would have protected child health and household food security through income effects for rural households.

The remainder of the paper is structured as follows. Section 4.2 describes the conceptual framework. Section 4.3 presents background and data while section 4.4 outline the empirical strategy and models specifications. Section 4.5 reports the results and Section 4.6 concludes.

4.2 Conceptual framework

4.2.1 Theory

Theoretically, I base the analysis on an intertemporal utility model with income uncertainty (Deaton, 1992; Townsend, 1994; Sadoulet and de Janvry, 1995). Risk aversion is assumed and an intertemporal household utility function over consumption is defined. At each point in time the realized utility level is unsecure as idiosyncratic economic, natural, biological, or health shock can occur and reduce consumption. Imposing the standard resource and feasibility constraints it can be shown that transitory idiosyncratic shocks do not reduce consumption if risk sharing is possible. Thus, consumption is smoothed and follows permanent income. However, it has been shown by Townsend (1994) that consumption smoothing and thus risk sharing is not perfect within villages. Whenever household consumption is influenced by contemporaneous own income and transitory shocks, households are not fully able to insure against risk and bear (some of) the consequences of idiosyncratic shocks, which results in variations in the instantaneous utility. As described by the theoretical model in Chapter 3, shocks affect household income and thus consumption. Instead of focusing on direct measures of consumption I take the more accurate measure of child health. Thus, I follow the approach by Thomas (1994) in that I consider health as input to the utility function.

In Chapter 3 – Section 3.2 I focused on the effects of weather variability, as simple extreme natural hazard in IPCC (2011) classification, on household welfare in terms of food consumption visualizing the potential channels of effects in Figure 3.1. In this section I concentrate instead on two major events: droughts (natural complex extreme event) and an increase in purchasing prices (non-natural event) while considering their concomitance with other natural, biological, economic and health shocks. The pathways through which multiple shocks can affect child health are several.

First, if household food security is not well insured and households are net buyers of food, an increase in (produced and imported) food prices may be a large income and health shock to household members. This is particularly true in Senegal where 20% of the population is undernourished, almost 30% of the population does not have adequate access to food and food imports account for more than 50% of the total merchandise exports (FAO, 2013). If food becomes more expensive and credit constraints are binding, households may be unable to provide the necessary food intake to children. Child health may remain unaffected if households have enough assets/savings to cope with the food price increases. Similar effects could stem from other *economic shocks* such as a decline in selling prices and the loss of employment of an adult member.

Second, *natural disasters* may affect household welfare and child health through their impact on agriculture, food security and health (IPCC, 2012). As already discussed in section 3.2.1, droughts, floods and extreme cold or warm days are likely to affect agriculture and rangeland productivity while potentially triggering losses of lives and infrastructures (IPCC, 2001). In contexts relying on subsistence agriculture, household food security may potentially be affected and this may indirectly worsen individual health outcomes depending on the intra-household allocation of resources (Thomas, 1990).

Third, indirect effects on agricultural productivity and health outcomes may also come from the development of vector/water/food-borne diseases (*biological shocks*). Natural hazards may provide particular conditions that allow pathogens already existing in the environment to develop and spread or make their life longer than their usual historic range, thus increasing the likelihood of biological hazards such as crop pests and livestock diseases (Anderson et al., 2004: 540; Piao et al., 2010). This applies to parasites affecting human beings as well: vector-borne diseases sensitive to weather changes such as the mosquitoes responsible of malaria and yellow fever, and diarrhea and other infectious diseases may increase due to the prolonged range and activity of pathogens (Haines et al., 2006: 2104). Hence, individuals may be affected in different ways by changes in illnesses and death rates as well as injuries and psychological disorders (*health shocks*) following complex extreme events such as floods, droughts and heat/cold waves (McMichael and Haines, 1997).

Finally, note that depending on the context, wetter/drier and/or warmer/colder weather may result also in positive effects on household welfare (see for example the work of Hsiang et al. (2013) suggesting that lower temperatures may help to reduce intergroup conflict risk). Moreover, certain adverse events may result in positive effects through resources redistribution in the household. For example, the migration of an unemployed member and/or the death of an unproductive member may allow resources previously allocated to that member to be redistributed to the remaining members. Depending on the additional income from the migrated member, pre-death medical expenses or funeral costs, and the earning ability of the dead member, household food security and welfare may improve (de Braw, 2011; Grimm, 2010).

In light of this discussion, analyzing the impact of shocks as stand alone events may provide an unclear and incomplete picture of what is occurring to household welfare in shocks-prone areas due to concomitance of shocks. A multi-shock analysis seems to be better suited to explore the effects of shocks on child health outcomes.

4.2.2 Child health outcomes and shocks: empirical literature

According to the World Health Organization - WHO[32] major differences in the growth of infants and children are largely based on environmental characteristics rather than ethnic differences. Following the meta-analysis of Charmarbagwala et al. (2004) determinants of child growth can be classified into three categories:

- Biological or child-specific characteristics as sex, age, birth order, genotype characteristics;
- Socio-economic status (SES) or household characteristics such as demographic composition of the household, level of education of the mother, household wealth status.
- Environmental quality and cultural factors or community characteristics, accounting for environmental risks depending for example on the availability of clean drinking water and

[32] WHO standardized measures to assess child growth status are weight-for-age, height-for-age and weight-for-age in comparison to the reference population in terms of Z-scores or standard deviation scores. Z-scores are calculated as the difference between the observed value and the median value of the reference population over the standard deviation value of the reference population. Z-scores refer to the reference mean or median value in terms of number of standard deviations, hence their summary statistics can be interpreted as descriptors of the population analyzed. Moreover, Z-scores are comparable across age groups, indicators and sex groups since the statistical relation to the reference population distribution is the same at all ages while z-scores do not depend on sex of the child (Onis and Blössner, 1997: 49). The child z-scores cut-off values used by WHO are: below -2 (above +2) standard deviations for low (high) indicators and below -3 (above +3) standard deviations for severe undernutrition (overweight). As the lack of evidence of wasting or thinness (captured by weight-for-height) is not a perfect signal of lack of nutritional problems, I will focus on weight for age.

hazardousness of the locality where the household lives, and quality in the services provided to the households.

The 35 studies considered for the meta-analysis constitute a sub-sample of studies focusing on height-for-age as indicator for long-term chronic malnutrition. Of a total of 61 studies Charmarbagwala et al. have collected, only seven explicitly account for variations in the prices of staples --a possible economic shock indicator in the recent literature (Barrera, 1990; Carter and Maluccio, 2003; Christiaensen and Alderman, 2003; Mackinnon, 1995; Marini and Gragnolati, 2003; Senauer and Garcia, 1991; Thomas et al., 1996)-- as possible determinants of child anthropometric characteristics, while only two explicitly include natural hazards (Bairagi, 1986; Quisumbing, 2003). [33] In the mid-2000s the academic interest about the impact of shocks on child health emerges and start to develop fast.

Studies on the effects of *economic shocks* on child health focus on aggregate income shocks. In general domestic economic crises in developing countries are found to have negative effects on child health outcomes (Ferreira and Schady, 2009). However, the effect would depend on village social capital or government/donors expenditures in health and services (Carter and Maluccio, 2003; Paxson and Schady, 2006). Recent studies focus on the effect of a change in commodity prices showing mixed procyclical or countercyclical child health variations. For example, Cogneau and Jedwab (2013) find that the 1990 cut of the administered cocoa producer price in Côte d'Ivoire reduced child health through a decrease in household income while Miller and Urdinola (2010) on coffee prices in Colombia show countercyclical child mortality. I add on the literature on economic shocks concentrating on the effects of an increase in purchasing prices in rural Senegal. Moreover, I acknowledge that concomitance of economic and other shocks categories may exacerbate the effects on child health.

Bengsston (2010) points out that recent studies on shocks and child health outcomes focus on specific *natural disasters* (mainly droughts and floods) using them as proxies for income reduction to identify failures in consumption smoothing in response to the identified natural hazards. For example, del Ninno and Lundberg (2005) showed that Bangladeshi children who experienced the big 1998 flood could not recover during the survey period although at the household level there seemed

[33] Moreover, besides the inclusion of shock variables, some studies on the determinants of child nutritional status published in the period covered by the meta-analysis of Charmarbagwala et al. (2004) were not included (for example, Deolalikar, 1996). A possible reason could be in the search strategy as highlighted in Chapter 2 or in some inclusion/exclusion criteria not explicitly mentioned in the paper.

to be successful consumption smoothing. Similarly, Hoddinott and Kinsey (2001) and Yamano et al. (2005) showed a decrease in child growth for the children that experienced drought in Zimbabwe and Ethiopia while Baez and Santos (2007) found higher child vulnerability in the aftermath of hurricane Mitch.[34] To make the economic magnitude of natural shocks more explicit Bengsston (2010) conducted a two-step estimation in which rainfall variations are used as instrument for income in the assessment of child weight responses to transitory income fluctuations. Furthermore, Bengsston (2010) and Skoufias and Vinha (2012) suggest additional negative effects on child outcomes from biological/health events such as malaria or communicable disease spreading but fall short to explicitly account for these events. Hence, I attempt to consider also these aspects.

Works on *health shocks* tend to focus on the effects of illnesses and mortality on income, consumption and child schooling. After a review of the literature Grimm (2010) argues that households cope fairly well with illness shocks while the evidence in case of mortality is not clear. In Indonesia Grimm finds that mortality does not significantly affect household welfare but this would depend on age and gender of the dead member. When a child or old member die, death costs would be compensated by the increase in available resources in the household, while adult mortality would trigger more costs and the need to resort to coping strategies. The literature on mortality and child schooling is quite prolific but constrained by data availability to cross-sectional studies (Case et al., 2004; Ainsworth and Filmer, 2002) except for Senne (2013) providing difference in difference panel evidence that both in the short and long run adult mortality negatively affect child education. Studies on the relationship between mortality shocks and child health are fewer and focused on long-term effects showing negative effects of parental mortality on child mortality or height-for-age (Ainsworth and Semali, 2010; Kadiyala et al., 2009). I add also on this literature focusing on short-term effects and stressing the linkages between shocks, food security and child weight-for-age. Focusing on the short-term is useful because it allows better highlighting of the main channels through which shocks affect households and/or child welfare, while also testing the effectiveness of prevention and mitigation measures already put in place in the context analyzed.

[34] Interestingly, Yamauchi et al. (2009) and del Ninno and Lundberg (2005) show that *ex-ante* human capital production and government programs for building resilience were able to partially mitigate the adverse effects of natural disasters on child health allowing for a better recovery as compared to the case of *ex-post* coping measures.

4.3 Background and data

4.3.1 Country background

Senegal is a Sahelian country in West Africa classified by the World Bank as a low-income nation. Per capita GDP has been increasing during the years from USD 662 in the early 1990s to USD 796 in the period 2010-12 but real GDP growth has slowed down since 2006 (World Bank, 2013). Senegal ranks 155th out of 187 countries for the Human Development Index, with a poverty headcount ratio at 2$ per day of 46.7%. Poverty differs considerably between rural and urban households: the poverty headcount ratio is more than 20% higher for rural households (57 against 33%) and the poverty gap index[35] suggests that poverty is more pronounced in rural areas. Similarly, food insecurity is a major concern: 20% of the population is undernourished while almost 30% of the population does not have adequate access to food (FAO, 2013).

Table 4.1 Per capita GDP level (constant 2005 USD) and growth, and value added per sector (% GDP).

	1990-1994	1995-1999	2000-2004	2005-2009	2010-2012
GDP per capita (constant 2005 UDS)	661.74	663.41	719.88	781.29	796.45
GDP growth (%)	0.88	4.55	4.20	3.76	3.49
Agriculture - value added (% GDP)	19.68	19.81	17.32	15.52	16.12
Industry - value added (% GDP)	23.22	23.75	24.49	22.86	23.05
Services- value added (% GDP)	57.10	56.44	58.76	61.64	62.94

Source: World Bank (2013).

Table 4.2 Urban/rural poverty in Senegal.

	2000-2004	2005-2009	2010-2012
Population (million)	***10.40***	***11.92***	***13.35***
Rural	59.34	58.43	57.44
Urban	40.66	41.57	42.56
Poverty headcount ratio at national poverty line (%)	***55.20***	***48.30***	***46.70***
Poverty headcount ratio at rural poverty line (%)	65.10	58.80	57.10
Poverty headcount ratio at urban poverty line (%)	41.20	33.60	33.10
Poverty gap at national poverty line (%)	***17.20***	***15.40***	***14.50***
Poverty gap at rural poverty line (%)	21.20	20.20	18.60
Poverty gap at urban poverty line (%)	11.70	8.80	9.20

Source: World Bank (2013).

[35] The poverty gap index considers how far the poor are on average from the poverty line.

Table 4.3 Food security and malnutrition in Senegal.

	2000-2004	2005-2009	2010-2012
Domestic food price level index	2.06	2.05	2.03
Domestic food price volatility index (SD)	24.66	12.38	32.97
Value of food imports in total merchandise exports	54.20	63.00	n.a.
Prevalence of undernourishment	23.67	16.93	20.40
Prevalence of food inadequacy	32.20	24.10	28.10
Prevalence of wasting (% children under 5)	10.00	8.70	9.80
Prevalence of stunting (% children under 5)	29.50	20.10	28.70
Prevalence of underweight (% children under 5)	20.30	14.50	19.20

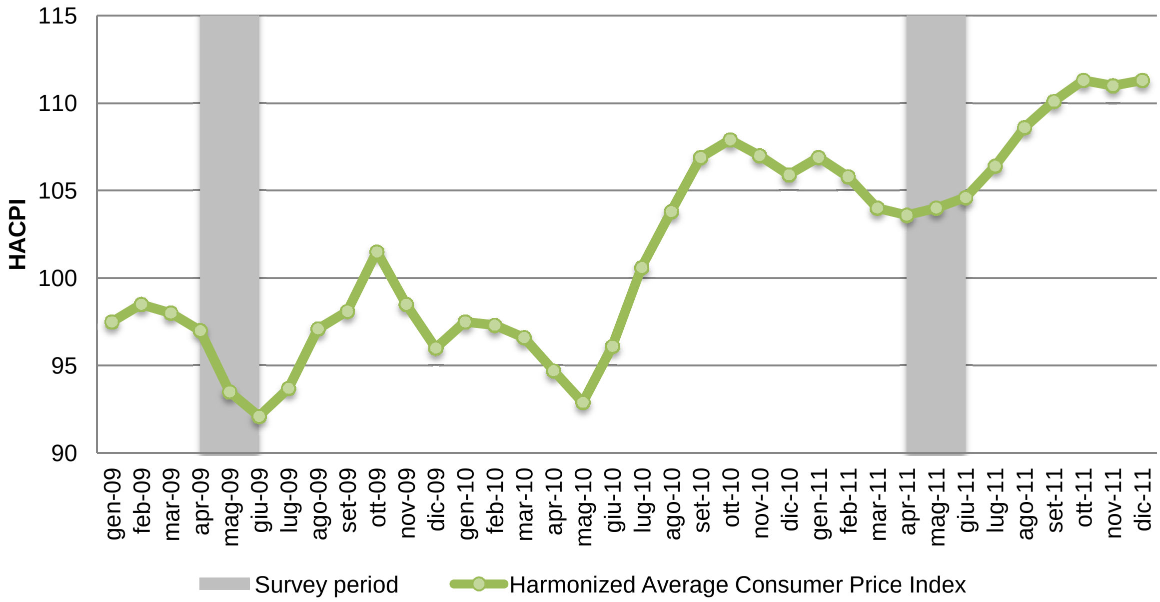
Source: FAO (2013).

Note: The domestic food price level index is calculated as the ratio between the food purchasing power parity and the general purchasing power parity. The domestic food price volatility index is the standard deviation (SD) of the deviations of domestic food price level index from the trend over previous five years.

Starting from 2002 the government of Senegal has been running a large-scale nutrition program (Nutrition Enhancement Program - Programme de Renforcement Nutritionnel, or NEP) to precisely tackle the problem of child malnutrition. The program has multisectoral interventions towards nutrition improvement and the World Bank has renewed funding for the program until 2014. The first phase of the program was between 2002 and 2006 mainly in the urban areas, not covered by the survey used for the analysis. The second phase took place between 2007 and 2011 extending interventions to rural areas where malnutrition was particularly high (Natalicchio, 2011). The 2011 assessment of the program states that the in 2006 it was covering 12% of children in rural areas while in 2011 the coverage surpassed 50% (Mulder-Sibanda, 2011). Unfortunately the questionnaire does not report information on household enrollment in NEP. Besides, since 2008 the Government of Senegal has been adopting several measures to improve rural households food security after the 2008 price increases to reduce household vulnerability to shocks. After setting up price controls, subsidies and rice (the major staple) redistribution in April-May 2008, the government started the Grand Agricultural Offensive for Food and Abundance (GOANA) to foster agricultural production and productivity. However, according to the World Food Programme – WFP (2013) the prevalence of both stunting and undernourishment among children below 5 years has worsened between 2005 and 2010 following a combination of food prices fluctuations and natural disasters.

Adding on the food insecurity burden, the year 2011 started with a surge in the price of domestic and international food products. The government promptly responded setting ceilings for the price of certain food products such as produced and imported rice, sugar and milk (FAO, 2013). Figure 4.1 shows the evolution of consumer prices in between the survey years. The increase in the domestic and international food prices in 2008 constituted a major shock to Senegalese households but the good 2008/2009 harvests helped to reduce household vulnerability by reducing the share of imported food (République du Sénégal, 2010). The series have since 2008 been rescaled accordingly. After the peak in June 2008, food prices rapidly declined reaching pre-crisis levels when the firs survey round was taking place. However, starting from June 2009 food prices began again to increase peaking at the end of 2010- beginning 2011 and fairly stabilizing at a new high level throughout the first half of 2011. Given these evolutions between 2009 and 2011 I expect households that directly experienced the 2011 food price increase to be more food insecure than households not exposed to the food price increase. Similarly, children leaving in households directly affected by the 2011 price increase are expected to present worse health conditions.

Figure 4.1 Harmonized consumer price index (food products) in Senegal 2009-2011 (base year: 2008).



Source: Agence Nationale de la Statistique et de la Démographie (AGNSD, 2013) and author's elaborations.

Note: The FAO food price index is calculated as the average of meat, dairy, cereals, oil and sugar price indices weighted with the average export shares of each of the groups for 2002-2004.

Moreover, Senegal is also prone to natural hazards. Rough estimates of the disaster profile of Senegal drawn from EM-DAT (2013) are presented in Table 4.4 and show that droughts and floods are the phenomena that mostly have affected the Senegalese population while epidemics are the phenomenon with the highest reported deaths. By disaster type droughts account in the last decade for more than 50% of people reported affected (EM-DAT, 2012). Hence I expect households that experienced both price and drought shocks to be more affected than households that did not experience either one or both the economic and natural adverse events.

Table 4.4 Top five natural and health disasters reported from 2004 to 2013.

Top 5	Disaster	Date	Affected
Affected people (no. of people)	Drought	2011	850,000
	Flood	2009	264,000
	Flood	2010	80,391
	Flood	2012	57,000
	Flood	2005	50,000
Killed people (no. of people)	Epidemic	2005	303
	Flood	2012	19
	Epidemic	2007	16
	Flood	2007	8
	Epidemic	2004	6
Economic damages (US$ x 1,000)	Flood	2012	10,000

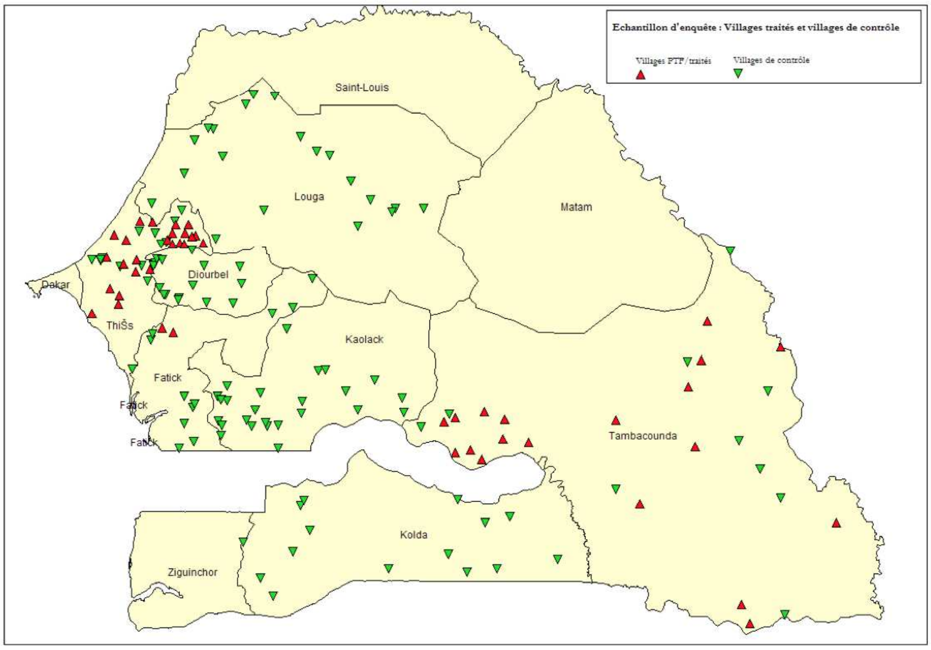
Source: EM-DAT (2012).

4.3.2 Data

Child health information is provided by a household survey carried out in eight regions of Senegal.[36] The survey was part of the program evaluation of a rural electrification initiative by the UNDP known as multifunctional platform. Two rounds of data are included: the baseline survey was conducted between April and July 2009 and the follow-up survey between April and June 2011, after the international food prices peak recorded in February 2011. Randomization of the households occurred at village level based on the lack of access to energy. Hence the sample is representative for rural Senegal in eight of 14 regions, in which income is most prevalently generated from subsistence agriculture.

[36] The regions are Diourbel, Fatick, Kaolack, Kedougou, Kolda, Louga, Tambacounda, and Thies according to the 2009 regional subdivision.

Map 4.1 Map of Senegal with surveyed villages.



Source: CERDI, IHEID, UGB (2009).

The analysis is restricted to children who were between 12 and 60 months and for whom anthropometric data are available. After excluding cases with z-scores beyond the [-4, +4] range, a total of 1490 and 1981 children are recorded in 2009 and 2011 respectively. As the primary sampling units are households, I observe attrition at the individual child level. But no systematic difference is found when comparing the characteristics of the panel dataset with those of the unrepeated observations. [37]

The shock module

Table 4.5 presents the shocks considered in the shock module of the survey with the number of observations that reported having experienced an adverse event in the current year (dummy variable = 1, zero if the shock was not experienced). Hence I am considering shocks occurred in the period January-April 2009 and 2011. In line with the analysis in the previous sections, an increase in purchasing prices is the adverse events that have mostly affected rural households in Senegal.

[37] Children without weight-for-age data were 1,732 in 2009 and 1,314 in 2011. Mean tests on observables did not suggest systematic differences between children with and without weight-for-age z-score. A detailed table with group comparison on observables is available upon request. Children with repeated observations were only 581 with some loss of representativeness, hence I preferred to use pooled cross-sections.

Economic shocks are followed by biological shocks; 25% (29%) of the households report livestock diseases in 2009 (2011). Natural hazards are reported by about 15% of the households in both rounds. Across shock categories I observe that significantly more adverse events are reported in 2011. [38]

Table 4.5 Shocks in the survey area 2009-2011.

	2009		2011		
Shocks	***Mean***	***St.Dev***	***Mean***	***St.Dev.***	**Difference**
Economic shocks	*0.51*	*0.65*	*0.82*	*0.52*	
Increase in purchasing prices	0.42	0.49	0.75	0.43	**-0.33*** **
Decline in selling prices	0.08	0.28	0.00	0.00	0.08
Loss of employment	0.01	0.10	0.07	0.25	**-0.05*** **
Natural hazard	*0.13*	*0.36*	*0.16*	*0.40*	
Drought	0.02	0.16	0.06	0.23	**-0.03*** **
Flood	0.01	0.09	0.02	0.14	**-0.01*** **
Cold wave	0.04	0.20	0.01	0.09	0.03
Bush fire	0.05	0.23	0.07	0.26	**-0.02*** **
Biological hazard	*0.25*	*0.49*	*0.29*	*0.49*	
Crop pest/insects invasion	0.04	0.20	0.04	0.19	0.00
Livestock disease	0.21	0.40	0.25	0.43	**-0.04*** **
Health shocks	*0.10*	*0.33*	*0.29*	*0.49*	
Epidemics	0.06	0.23	0.23	0.42	**-0.17*** **
Death of a member	0.04	0.20	0.05	0.23	**-0.01*** **
N. households		*1,490*		*1,981*	

Source: Author's elaborations.

Note: *** stands for p-value<0.01. Difference in shock incidence is in bold when incidence is significantly higher in 2011.

The extent of interdependencies between different shock categories is presented in Tables 4.6 and 4.7 for the two survey years. Notably, in 2009 droughts seem to be positively and significantly correlated with the occurrence of crop pests, loss of employment and increasing purchasing prices. Similarly, floods are correlated with livestock diseases and price variations. Increasing purchasing prices are also positively correlated with the occurrence of an extreme cold period and bush fire.

Pairwise correlations slightly differ in 2011. In particular, except for extreme cold and fire natural shocks are not significantly correlated with increase in purchasing prices in 2011, while loss of employment seems positively and significantly correlated to the occurrence of all other shocks except bush fire.

[38] External validity of the survey shock data is confirmed by the descriptive statistics of the household survey in rural Senegal presented by the World Food Programme in 2010 (Republique du Senegal, 2010).

Table 4.6 Correlation between different shocks for the 2009 survey.

Shock type			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Natural	(1)	Drought	1										
	(2)	Flood	0.037	1									
	(3)	Extreme cold	0.032	-0.018	1								
	(4)	Fire	0.000	0.049	0.055*	1							
Biological	(5)	Livestock disease	-0.028	0.111*	0.018	0.165	1						
	(6)	Crop pest	0.099*	-0.018	0.094*	0.103*	0.022	1					
Health	(7)	Epidemics	-0.033	-0.018	0.161*	0.026	0.070*	0.010	1				
	(8)	Death of a member	0.052*	-0.021	-0.009	0.017	0.128*	0.022	0.122*	1			
Economic	(9)	Loss of employment	0.109*	-0.009	0.044	-0.025	-0.037	-0.021	0.011	0.002	1		
	(10)	Decline in selling prices	0.092*	0.200*	-0.014	0.132*	-0.017	0.074*	-0.062*	-0.003	0.086*	1	
	(11)	Increase in purchasing prices	0.152*	0.101*	0.135*	0.122*	0.144*	0.095*	0.077*	-0.039	0.069*	0.285*	1

Source: Author's elaborations.

Note: * stands for level of significance greater or equal to 0.05.

Table 4.7 Correlation between different shocks for the 2011 survey.

Shock type			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Natural	(1)	Drought	1										
	(2)	Flood	-0.004	1									
	(3)	Extreme cold	0.117*	0.027	1								
	(4)	Fire	-0.046*	0.100*	-0.026	1							
Biological	(5)	Livestock disease	0.010	-0.013	0.035	0.080*	1						
	(6)	Crop pest	0.180*	-0.027	0.098*	0.026	0.079*	1					
Health	(7)	Epidemics	0.074*	-0.033	0.196*	0.000	0.048*	0.060*	1				
	(8)	Death of a member	0.026	0.010	0.014	-0.038	0.189*	0.032	0.064*	1			
Economic	(9)	Loss of employment	0.231*	0.187*	0.330*	-0.020	0.103*	0.372*	0.181*	0.126*	1		
	(10)	Decline in selling prices	.	.	.	.	.	.	.	.	.	.	
	(11)	Increase in purchasing prices	0.017	0.011	0.053*	0.082*	0.126*	0.087*	-0.004	0.150*	0.136*	.	1

Source: Author's elaborations.

Note: * stands for level of significance greater or equal to 0.05.

Sample descriptive statistics

Table 4.8 presents the descriptive statistics of the children in the dataset for which anthropometric data are available. The sample is gender balanced. In 2009 on average the children are 29 months old and show 1.10 level of underweight. I use the 2006 growth standards for attained weight by the World Health Organization (WHO & UNICEF, 2009). The indicator of child health is a standardized measure relative to an international reference population and is expressed in terms of standard deviations (Z-scores). First of all I observe that weight-for-age improves over time in the sample at hand. As aforementioned, this could be due to the national child nutrition program. Moreover, some changes occurring in between the survey rounds hint to a gradual structural change in household socio-economic conditions.

Children's households have on average 13 to 15 members, about 25% of the members are children below 5 years in both rounds. In 2011 less children leave in households without being assisted by their mothers, while mother's literacy has increased between rounds. Wealth and connectedness also improved. On average households own more poultry, mobile phones and radios. These changes may account for positive effects on child health. The presence of the mother is likely to increase the attention towards the health needs of the child both at the child level and at the household level, while maternal literacy (and education) may account for higher abilities in processing health and nutrition information (Christiaensen and Alderman, 2004; Glewwe, 1999). The combined effect of increasing maternal education and connectedness would also have positive effects on child health by increasing the access to available nutrition information (Glewwe, 1999; Thomas et al., 1991) and information risk management mechanisms in case of shocks.

Table 4.8 Descriptive statistics of selected control variables for rural households in Senegal.

	2009		2011		
Variable	Mean	St. Dev	Mean	St. Dev	Difference
Weight-for-age (WAZ)	-1.101	1.426	-0.401	1.640	- 0.700***
Sex	0.464	0.499	0.498	0.500	- 0.034
Age (months)	29	12.433	34	14.766	- 5.272**
Missing date of birth (=1)	0.811	0.392	0.798	0.402	0.013
Age Head HH	52	14.544	54	15.332	-1.537***
Sex Head HH[a] (Female=1)	0.023	0.152	0.025	0.155	-0.001
Mother is out of the household (=1)	0.050	0.219	0.036	0.187	0.014**
Age Mother	29	7.442	30	7.361	-0.868***
Mother can read and write (=1)	0.155	0.362	0.177	0.382	-0.022*
Mother is head of household (=1)	0.005	0.068	0.004	0.063	0.001
Mother is wife of the head HH (=1)	0.520	0.500	0.475	0.499	0.046*
Mother is daughter of head HH (=1)	0.038	0.190	0.041	0.199	-0.004
Mother is not a relative	0.027	0.162	0.016	0.126	0.011**
Household size	14	6.360	16	7.180	-1.520***
Share of children <5 in household	0.254	0.104	0.241	0.100	0.013***
Poultry	0.568	0.495	0.671	0.470	-0.102***
Livestock	0.942	0.235	0.953	0.213	-0.011
Water					
(1) own tap	0.212	0.408	0.236	0.425	-0.024*
(2) public tap	0.273	0.446	0.246	0.431	0.027*
(3) protected well	0.091	0.287	0.039	0.195	0.051***
(4) neighbor tap	0.011	0.106	0.012	0.109	-0.001
(5) non-protected well	0.293	0.455	0.334	0.472	-0.042*
(6) hole	0.072	0.259	0.117	0.321	-0.044***
(7) other	0.048	0.215	0.016	0.126	0.032***
Toilet					
(1) none or external	0.211	0.408	0.164	0.370	0.047***
(2) water sewer	0.009	0.097	0.004	0.059	0.006**
(3) septic tank	0.031	0.173	0.089	0.285	-0.058***
(4) covered latrine	0.377	0.485	0.296	0.457	0.081***
(5) uncovered latrine	0.283	0.450	0.235	0.425	0.046**
(6) other	0.089	0.284	0.212	0.408	
Own Mobile (=1)	0.671	0.470	0.884	0.320	-0.213***
Own radio (=1)	0.739	0.439	0.814	0.389	-0.075***
N. parcels cultivated	3.023	1.651	3.071	1.444	-0.048
Size of land cultivated (Ha)	6.762	6.093	5.754	4.815	1.008***
Food (in)security (weeks of food scarcity)	6.384	6.012	4.016	4.816	2.368***
N		1,490		1,981	

Source: Author's elaborations.

Note: * stands for p-value < 0.10 , ** stands for p-value < 0.05 , *** stands for p-value < 0.01.

The last row of Table 4.8 reports a household food insecurity indicator for the households in which the children reside: food insecurity is measured as the number of weeks of food scarcity (stocks of cereals are exhausted) at the time of interview. On average in 2009 children were reported leaving in a household where the stock of cereals (and/or rice) had been exhausted for six weeks while in 2011 the weeks of food scarcity decreased by one third. Thus households in 2011 appear to be less food insecure in 2011. Note that seasonal effects are minimized since both the surveys were conducted during the same agricultural season.

The econometric model employed in the multivariate analysis is introduced in the next section. Before, in Table 4.9 I present non-parametric difference-in-difference (DD) estimates on the 2009 and 2011 cross sections of children with available weight-for-age and food (in)security data by year and child increasing price and drought shocks experience. Note that children reported leaving in households that experienced the two shocks in 2009 have lower weight-for-age than the non-shock children, although household food security is higher in the latter case. This could be explained by possible income effects for net producer households or household preferences for child health in times of distresses. Despite the structural change in place between rounds, possible income effects and household preferences, child weight-for-age in 2011 is lower for children leaving in households that experienced an increase in purchasing prices (or a drought), the difference in difference estimate also supporting negative shocks effects on child weight-for-age. Importantly the drought DD estimate is most significant and accounting for 76% of the weight-for-age standard deviation in 2011. By contrast, both increasing purchasing prices and drought shocks seem to worsen food security in 2009, accounting for an increase in the number of weeks since the household exhausted its cereals stocks. In 2011 food security seems rather unaffected by price and drought shocks and the DD estimate seems to confirm the prevalence of a structural improvement of food security between rounds. However, these results do not consider the three classes of child health determinants, namely biological or child-specific characteristics, socio-economic status or household-specific characteristics and environmental quality and cultural factors or community characteristics. The third set of characteristics is also crucial in determining food security since this variable tends to be related to space and time dimensions (Hoddinott, 1999).

Table 4.9 Non parametric difference in difference.

	2009		2011		
	Price shock	No Price Shock	Price shock	No Price Shock	DD
Weight-for-age (WAZ)	-1.048	-1.139	-0.438	-0.287	-0.242**
Food (in)security (weeks of food scarcity)	7.02	5.92	4.01	4.00	-1.08***
	2009		2011		
	Drought shock	No Drought	Drought shock	No Drought	DD
Weight-for-age (WAZ)	-0.895	-1.106	-1.248	-0.348	-1.111***
Food (in)security (weeks of food scarcity)	9.35	6.31	4.46	3.99	-2.568**

Source: Author's elaborations.

Note: * stands for p-value < 0.10 , ** stands for p-value < 0.05 , *** stands for p-value < 0.01.

4.4 Empirical model

The estimation procedure follows three steps.

4.4.1 Basic model: partial and multi-shock analysis

Considering that child, household and community characteristics could be correlated with child weight-for-age I initially estimate a simple child health model including several observable child, mother, and household characteristics to avoid omitted variables bias. The basic estimation equation can then be written as:

$$Health_{iht} = \alpha + \beta\, CC_{iht} + \gamma HH_{ht} + \delta_1 NAT_{ht-1} + \delta_2 BIO_{ht-1} + \delta_3 ECN_{ht-1} + \delta_4 HLT_{ht-1} + \rho_t + \lambda_i + \varepsilon_{iht} \quad (4.1)$$

where $Health_{iht}$ is the weight-for-age Z-score pertaining to child *i* in household *h* in year *t*. CC_{iht} is the vector of child and maternal characteristics. HH_{ht} contains the household characteristics and wealth characteristics. The occurrence of shocks is observed at the household level; NAT_{ht-1} is the vector of natural hazards experienced by the household in the three to six months prior to the survey, BIO_{ht-1} represents biological hazards, economic shocks are collected in ECN_{ht-1} and health related shocks in HLT_{ht-1}. Structural change is captured by the year dummy ρ_t while λ_i accounts for village-year-fixed effects and ε_{iht} is the error term. Strict exogeneity of shocks with respect to observable child, household and community characteristics would allow unbiased OLS estimates of the average impact of shocks on child weight-for-age.

4.4.2 Price (drought) DD of weight-for-age

Given the improvements in 2011 but also the increased incidence of shocks and the generalized increase in purchasing prices in 2011 I am interested in the comparison of child weight-for-age for children reported leaving in households that experienced the price shock before and after the government engagement into pro-nutrition and pro-agricultural development measures. Hence I estimate the following DD model with village-year fixed effects:

$$Health_{iht} = \alpha + \beta\, XCC_{iht} + \gamma HH_{ht} + \delta_1 NAT_{ht-1} + \delta_2 BIO_{ht-1} + \delta_3 ECN_{ht-1} + \delta_4 HLT_{ht-1} + \rho_t + \sigma PricesIncrease_{2011} + \lambda_i + \varepsilon_{iht} \quad (4.2)$$

where the additional term $PricesIncrease_{2011}$ interacts the increase in purchasing prices shock with the dummy for the year 2011. Other variables are defined as above. A similar model is also estimated to compare a drought shock before and after the structural change, introducing the additional term $Drought_{2011}$ (interacting the drought shock dummy variable with the dummy for the year 2011) in place of $PricesIncrease_{2011}$.

4.4.3 Misfortunes never come singly: increasing prices in times of drought (DDD model)

In the final step I consider the effects of concomitant increasing prices and drought shocks comparing children between rounds:

$$\begin{aligned} Health_{iht} = \alpha + \beta\, CC_{iht} + \gamma HH_{ht} + \delta_1 NAT_{ht-1} + \delta_2 BIO_{ht-1} + \delta_3 ECN_{ht-1} + \delta_4 HLT_{ht-1} \\ + \rho_t + \sigma_1 PricesDrought_{ht-1} + \sigma_2 PricesIncrease_{2011} + \sigma_3 Drought_{2011} \\ + \sigma_4 PricesDrought_{2011} + \lambda_i + \varepsilon_{iht} \end{aligned} \qquad (4.3)$$

where $PricesDrought_{ht-1}$ interacts the increase in purchasing prices with the occurrence of a drought (shocks concomitance effect independently of the year), $PricesIncrease_{2011}$ interacts the increase in purchasing prices shock with the dummy for the year 2011 and $Drought_{2011}$ interacts the drought shock dummy variable with the dummy for the year 2011. The variable of interest is $PricesDrought_{2011}$ interacting both the purchasing price and drought shock dummies with the dummy for the year 2011. Hence σ_4 will account for the effects of the two shocks concomitance on child weight-for-age, while considering the structural change in place between the two rounds. Other variables are defined as above.

4.5 Results and robustness checks

The results for the impact of adverse events on child nutritional status are presented in Table 4.10. I account for household size and composition (share of children below 5 years in the household) and parental characteristics, access to water and sanitation and wealth indicators (poultry, livestock and land ownership). Indicator variables for the ownership of a radio and/or mobile phone in the household are included as both indicators of wealth and connectedness. These devices allow the household to get access to news and information about healyh and shocks occurring within and outside the country. Similarly, I control for a time trend to capture structural changes (a dummy taking value 1 for 2011 observations, 0 for 2009). In addition, following the approach of Cogneau and Jedwab (2012) and Senne (2013) I control for village-year fixed effects including dummies for the village of residence interacted with year to control for all unobserved village-specific characteristics and trends related to shocks and child health. Standard errors are clustered at the village level to account for within village correlation of the error term. Finally I include dummies accounting for economic, natural, biological and health shocks. Negative and significant coefficients associated with a shock variable indicate that the occurrence of the respective shock affects child health negatively. The non-significance of the coefficient pertaining to a shock variable does not necessarily suggest that the specific shock did not have any effects on child nutritional status or on other indicators of household welfare. It rather may suggest that, on average, household may have been able to mitigate the adverse effects of the shock thanks to (*ex-ante/ex-post*) successful coping strategies.

A first glance to table 4.10 allows making three initial comments. First the year dummy is positive and significant, supporting the argument of a structural change occurring in between the two survey rounds. Second, I excluded certain shocks (shocks with small incidence or shocks not particularly related to the analysis) to allow the estimation of more parsimonious models in the subsequent steps and rule out potential multicollinearity driven by certain shocks interdependencies. Results including the full set of shocks do not sensibly differ from the ones in Table 4.10 and are available upon request. Third, sign and level of significance of the shocks considered remain stable across specifications allowing discussing coherent shocks and child weight-for-age pathways across different models.

4.5.1 Results of the partial and multi-shock analysis

Results of the partial shock analysis (including shocks singly in the specification of the model) are reported in specifications (1) to (7) while specification (8) considers shocks altogether. Note that coefficients magnitudes vary slightly in the multi-shock specification. Crop pests and a member loss of employment experience the higher increase in magnitude in the multi-shock specification. These increases seem to be linked to their correlation to drought shocks as suggested by Tables 4.6 and 4.7. For example, the occurrence of a drought in the planting season could hamper crop growth, thus resulting in a lower labor demand for the harvesting season. Similarly, droughts could weaken crops resistance and/or favor the development of pests and insects. However, respective coefficients are non significant. On the other hand, on average droughts and a member loss of employment seem to have adverse effects on child health. Droughts negative effects could be associated with losses of agricultural income for rural households relying primarily on farm activities. Similarly, the loss of employment of a member can result in a decreased income at the individual and household level. Both shocks account for about 40% (30%) of the 2009 (2011) child weight-for-age standard deviation. I explore more in detail the effects of drought between rounds in the DD and DDD results. In contrast with my expectations, I find that extreme cold episodes and death of a member seem to have beneficial effects on child weight-for-age. Considering that Senegal is a tropical country, a decrease in temperatures could have resulted in beneficial effects for both agricultural production and household members productivity and livelihood (see for example Hsiang et al., 2013; Lobell et al., 2011). Moreover, crosschecking with survey enumerators and Senegalese temperature series suggest that the lower temperature experienced in the survey years were not extreme (although recorded as such by some respondents). Finally, a household member's death seem to have a positive effect on child weight for age accounting for 13 to 18% of the Z-score standard deviation. In line with the discussion in the previous sections and the focus on the short-term, this result suggest that a reduction in consumption units in the household would prevail on funeral costs and reduced-income costs triggered by the loss of a (income earner) member.

4.5.2 Structural change and price (drought) DD

Specifications (9) and (10) present increasing prices and drought DD estimates conditional on child, household and village observables and the survey year to consider fundamental changes occurring between 2009 and 2011 in the survey areas. Conditional DD estimates (the year-shock dummy variable) are in line with the non-parametric estimates for child weight-for-age in Table 4.9 suggesting a negative effect of both increasing prices and droughts although the considerable improvements in 2011. This highlights the need to implement measures to protect child health from certain adverse events while considering that household could experience at the same time other connected distresses (such as crop pests in the aftermath of a drought).

Table 4.10 Econometric results, village-year fixed effect estimations clustered at the village level.

	Dependent variable: Child Weight-for-Age										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Year 2011 (=1)	0.802***	0.804***	0.787***	0.771***	0.795***	0.804***	0.783***	0.834***	1.014***	0.860***	1.037***
	(0.0839)	(0.0819)	(0.0835)	(0.0881)	(0.0836)	(0.0835)	(0.0834)	(0.088)	(0.129)	(0.087)	(0.130)
Drought_1	-0.47***							-0.434**	-0.452**	0.283	-0.69***
	(0.177)							(0.175)	(0.175)	(0.402)	(0.161)
Extreme cold_1		0.513***						0.544***	0.503**	0.538***	0.497**
		(0.193)						(0.191)	(0.194)	(0.193)	(0.197)
Crop pest_1			0.0500					0.115	0.111	0.111	0.0904
			(0.164)					(0.167)	(0.166)	(0.156)	(0.154)
Increase purchasing prices_1				0.0434				0.0323	0.207*	0.022	0.183
				(0.0779)				(0.080)	(0.120)	(0.080)	(0.118)
Decrease selling prices_1					0.114			0.132	0.0538	0.104	0.0214
					(0.195)			(0.205)	(0.204)	(0.206)	(0.207)
Loss employment_1						-0.460*		-0.501**	-0.489**	-0.481**	-0.470**
						(0.238)		(0.234)	(0.233)	(0.235)	(0.235)
Death of member_1							0.224**	0.238**	0.227**	0.247**	0.240**
							(0.108)	(0.109)	(0.111)	(0.109)	(0.111)
Year 2011 * Incr.Prices_1									-0.328*		-0.321*
									(0.178)		(0.178)
Year 2011 * Drought_1										-0.906**	-0.196
										(0.416)	(0.282)
Incr.Prices_1 * Drought_1											1.035**
											(0.475)
Year 2011 * Incr.Prices_1 * Drought_1											-0.702
											(0.522)
Constant	-1.29***	-1.47***	-1.44***	-1.46***	-1.44***	-1.46***	-1.43***	-1.32***	-1.35***	-1.25***	-1.28***
	(0.356)	(0.348)	(0.349)	(0.348)	(0.349)	(0.350)	(0.347)	(0.354)	(0.360)	(0.351)	(0.358)
Observations	3,471	3,471	3,471	3,471	3,471	3,471	3,471	3,471	3,471	3,471	3,471
R-squared	0.217	0.217	0.215	0.215	0.215	0.216	0.215	0.222	0.224	0.224	0.226
Number of clusters (villages)	165	165	165	165	165	165	165	165	165	165	165

Source: Author's elaborations.

Note: Additional control variables included are age and sex of the child, head of the household and mother's age and sex, if the mother reside in the household, mother's literacy, if the mother is or not related to the head of the household, number and size of parcels of land cultivated, ownership of poultry, livestock, radio and mobile phone, water and toilet facilities dummies. *, **, *** stand for level of significance at 10, 5 and 1% respectively.

4.5.3 Misfortunes never come singly? Competing effects

When I consider the DDD estimate accounting for concomitance of an increase in purchasing prices and drought episodes after 2011 I find negative but non-significant effects on child weight-for-age. Given the 2011 considerable improvements in child weight-for-age but the higher incidence of shocks, a closer look to the variables accounting for intermediate effects can shed some light on this result.

Firstly, the 2011 structural change dummy increased in magnitude with respect to earlier specifications, suggesting that analyzing the effects of an increase in purchasing prices in concomitance with a drought shock would help to better disentangle the relationship between child health and fundamental changes in the time covered by the survey. Secondly, The price-year dummy is negative and significant as in the non-parametric and parametric prices-DD analysis. However in comparison with the drought-DD analysis the coefficient of the drought-year dummy has a very low magnitude and is no longer significant. Thirdly and more important, the effects of the concomitance of increasing prices and drought shocks is largely captured by the prices-drought dummy. The coefficient of this variable (σ_1 in equation 4.3) accounts for positive and significant effects in the order of 60 to 70% of the standard deviation of child weight-for-age. In economic terms this suggests competing price and income effects. Below I attempt to consider the relevant channels of effects.

Local effects

I expect households located in the same areas to have similar characterisitcs, risk and food security profiles. Moreover, the national nutrition program launched in Senegal and gradually spreading in rural areas in more recent years aims precisely to reduce child malnutrition through increased community nutrition activities such as growth monitoring, food supplements for children underweight and information-education-communication sessions for pregnant women (Natalicchio, 2011). The inclusion of village-year fixed effects in the analysis implies that I am controlling for unobservable characterisitcs shared by households in the same village. The village-year fixed effects also imply that the shock effect that influence child health is only the one differentially affecting children that experienced and did not experience the structural change and the specific shock analyzed in the same environment.

Time allocation

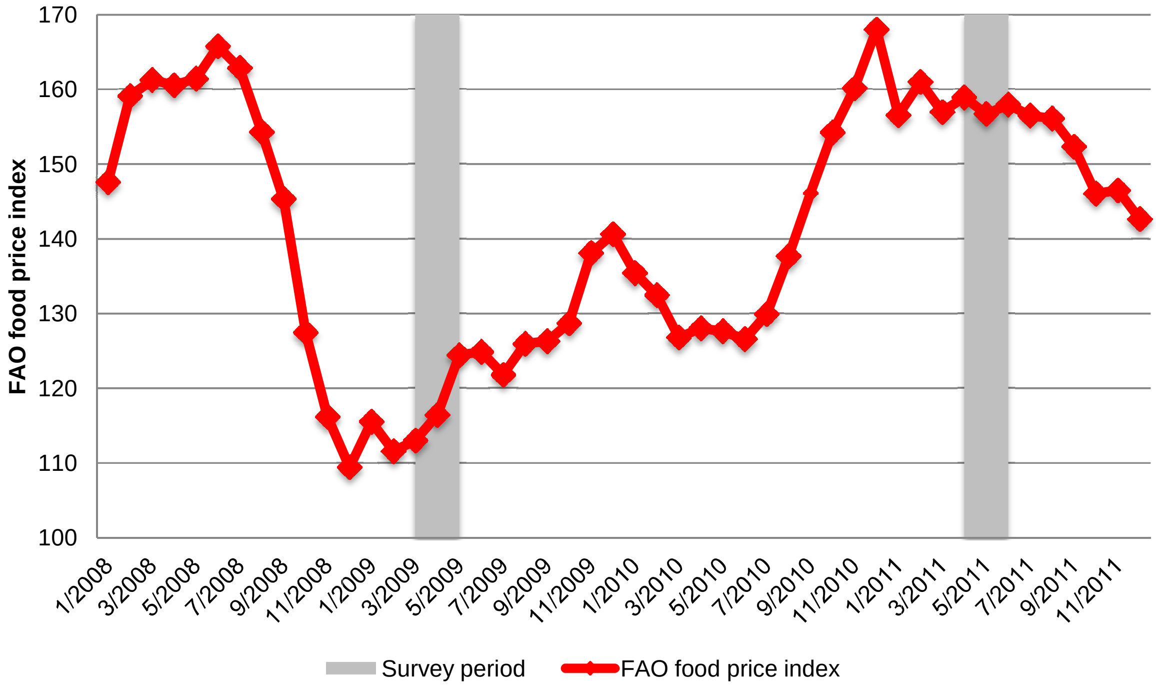
An increase in purchasing prices could push households to rely more on ownproduced food products. However, if a drought strikes during inflationary periods rural households members may find more profitable to reallocate their work to off-farm activities and/or child care in rural household (Miller and Urdinola, 2010). This reallocation of time could have beneficial effects on child health through the substitution between farm and off-farm income and/or an increase in the time dedicated to children (Cogneau and Jedwab, 2012). Imperfect labor markets and the short-term nature of my analysis suggest low availability of off-farm activities in the short-term in the context analyzed, while I refer to future analyses to assess the child care channel.

Income effects

Positive effects of concomitant increasing purchasing prices and droughts on child weight-for-age may be driven by an increased income for farmers. Farmers experiencing drought may have a decrease in land productivity and agricultural production. A generalized drought-induced reduction in the supply of agricultural products may increase the price of food items sold on the market, thus increasing the income of net food producers, with positive effects on the health of children leaving in the household. This positive income effect may also be enhanced by the competitiveness gains derived by a concomitant increase of the price of imported food products. Being Senegal highly dependent on food imports, I have to consider this particular effect. Figure 4.2 presents the evolution of international food prices from 2008 to 2011. Notably, households interviewed in 2009 seem not to have experienced major international food price shocks (their level sharply declining after the peak in 2008) but they may have experienced international food prices peaks at the beginning of 2011. Although the survey did not specifically ask for the domestic or international source of the price increase, the specific food prices peak in 2011 should (and seems to) be reflected in the price-year interaction term, leaving the increase in domestic food prices effects in drought times to be captured by the price-drought interaction term. Hence I argue that the occurrence of a drought shock in rural Senegal during a period of increasing prices allowed to leave child health unaffected by the increase in prices thanks to positive income effects[39].

[39] This is in line with agricultural household model mechanisms (Singh et al., 1986).

Figure 4.2 FAO food price index 2008-2011 (base year: 2002-2004).



Source: FAO (2013)

Note: The FAO food price index is calculated as the average of meat, dairy, cereals, oil and sugar price indices weighted with the average export shares of each of the groups for 2002-2004.

Food security

Concomitant price increases and drought risk adverse effects on child weight-for-age could also have been mitigated by a structural improvement in household food security levels between the two rounds as suggested by the descriptive statistics in Table 4.8. The non parametric DD suggested that the 2011 improvements effects prevailed on the adverse shock effects. The estimation of specification (11) using the food insecurity indicator as dependent variable confirms that food security worsens in times of drought but 2011 fundamental changes and positive income effects due to concomitance of price and drought shocks leave food security (and child weight-for-age) unaffected un 2011. Whether the food security improvement is primarily driven by the structural change or by the argued income effects have still to be investigated more accurately.

4.6 Conclusions

In this chapter I focused on the impact of natural disasters, economic, biological, and health shocks on child weight-for-age highlighting the channels through which child and respective rural households may have (or have not) been affected. I focused on the context of rural Senegal and I exploited difference in difference and triple difference strategies to explore the effects of non-concomitant and concomitant increases in purchasing prices and drought shocks. I show that the fundamental changes in 2011 seemed not enough to insure child health if the respective household experienced non-concomitant higher purchasing prices or a drought. However, if the household experienced both shocks the net effect on child weight-for-age in 2011 was not significant. I suggest that income effects would have protected child health by concomitant drought and price shocks.

The result of the analysis is very peculiar since it emphasizes that eventually shock concomitance may result in positive or non-significant effects on the outcome variable. From the perspective of the policy maker the various channels of effects have then to be considered in long-term programs designs and short-term intervention decisions in order to minimize households and individual vulnerability before the (non) natural shocks occur while maximizing their resilience *ex-post*. For example, if the analysis in this Chapter highlighted positive income effects from concomitant price and drought shocks for children in rural households, nothing is said about the effects of these shocks in urban areas. Ultimately the effects on urban children and household could have been very different.

To conclude, the analysis in this Chapter still needs further work to tackle exisisting methodological and research issues such as the provision of a test for the underlying parallel trends assumption or a deeper analysis of possible households coping strategies.

References

AGNSD (2013) *Publication mensuelles.* Accessed January 2014, available at http://www.ansd.sn/publications_mensuelles.html.

Ainsworth, M. and D. Filmer (2002) *Poverty, AIDS, and children's schooling: a targeting dilemma.* Washington, DC: World Bank.

Ainsworth, M. and I. Semali (2010) *The impact of adult deaths on children's health in Northwestern Tanzania.* Washington, DC: World Bank.

Alderman, H., J. Hoddinott and B. Kinsey (2006) 'Long term consequences of early childhood malnutrition', *Oxford Economic Papers* 58 (3): 450-474.

Anderson, P.K., Cunningham, A.A., Patel N.G., Morales F.J., Epstein P.R. and Daszak, P. (2004) 'Emerging Infectious Diseases of Plants: Pathogen Pollution, Climate Change and Agrotechnology Drivers', *Trends in Ecology & Evolution* 19 (10): 535-544.

Baez, J. and I. Santos (2007) 'Children's vulnerability to weather shocks: A natural disaster as a natural experiment', Working Paper. Available at SSRN: <http://ssrn.com/abstract=903684>.

Bairagi, R. (1986) 'Food crisis, nutrition, and female children in Rural Bangladesh', *Population and Development Review* 12 (2): 307-315.

Barrera, A. (1990) 'The role of maternal schooling and its interaction with public health programs in child health production', *Journal of Development Economics* 32 (1): 69-91.

Beegle, K., J. De Weerdt, J. Friedman and J. Gibson (2012) 'Methods of household consumption measurement through surveys: Experimental results from Tanzania', *Journal of Development Economics* 98: 3-18.

Bengtsson, N. (2010) 'How responsive is body weight to transitory income changes? Evidence from rural Tanzania', *Journal of Development Economics* 92 (1): 53-61.

Block, S.A., L. Kiess, P. Webb, S. Kosen, R. Morench-Pfanner, M.W. Bloem and C.P. Timmer (2004) 'Macro shocks and micro outcomes: child nutrition during Indonesia's crisis', *Economics and Human Biology* 2 (1): 21-44.

Carter, M. And J.A. Maluccio (2003) 'Social capita land coping with economic shocks: An analysis of stunting of South African children', *World Development* 31 (7): 1147-1163.

Case, A., C. Paxson and J. Ableidinger (2004) 'Orphans in Africa: parental death, poverty, and schooling enrollment', *Demography* 41 (3): 483-508.

CERDI, IHEID and UGB (2009) *Evaluation d'impact du programme PTF au Sénégal. Rapport sur la situation de reference.* Geneva: The Graduate Institute. (mimeo)

Charmarbagwala, R., M. Ranger, H. Waddingotn and H. White (2004) 'The determinants of child health and nutrition: a meta-analysis', manuscript. Washington, DC: World Bank.

Christiaensen, L. and H. Alderman (2004) 'Child malnutrition in Ethiopia : can maternal knowledge augment the role of income ?', *Economic Development and Cultural Change* 52 (2) : 287-312.

Cogneau, D. and R. Jedwab (2012) 'Commodity price shocks and child outcomes : the 1990 cocoa crisis in Côte d'Ivoire', *Economic Development and Cultural Change* 60(3) : 507-534.

de Braw, A. (2011) 'Migration and child developments during the food price crisis in El Salvador', *Food Policy* 36 (1): 28-40.

Deaton, A. (1992) 'Saving and income smoothing in Côte d'Ivoire', *Journal of African Economies* 1(1): 1-24.

del Ninno, C. and M. Lundberg (2005) 'Treading water. The long-term impact of the 1998 flood on nutrition in Bangladesh', *Economics and Human Biology* 3 (1): 67-96.

Deolalikar, A.B. (1996) 'Child nutritional status and child growth in Kenya: socioeconomic determinants', *Journal of International Development* 8 (3): 375-393.

Dercon, S. (1996) 'Risk, Crop Choice, and Savings: Evidence from Tanzania', *Economic Development and Cultural Change* 44 (3): 485-513.

Dercon, S. (2004) 'Growth and Shocks: Evidence from Rural Ethiopia', *Journal of Development Economics* 74 (2): 309-329.

Dercon, S., J. Hoddinott and T. Woldehanna (2005) 'Shocks and Consumption in 15 Ethiopian Villages, 1999-2004', *Journal of African Economies* 14 (4): 559.

Dercon, S. and P. Krishnan (2000) 'In sickness and in health: Risk sharing within households in rural Ethiopia', *Journal of Political Economy* 108 (4): 688-727.

EM-DAT (last update 2012) *The OFDA/CRED International Disaster Database.* Brussels, Belgium: Université Catholique de Louvain. Accessed 16 June 2012 <www.emdat.be >.

Ezra, M. (2001) 'Demographic responses to environmental stress in the drought- and famine-prone areas of northern Ethiopia', *International Journal of Population Geography* 7 (4), 259–279.

Fafchamps, M., C. Udry and K. Czukas (1998) 'Drought and saving in West Africa: are livestock a buffer stock?', *Journal of Development Economics* 55 (2): 273-305.

FAO (2013) *FAO Food Security Indicators*. Available at http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/.

Ferreira, F.H.G. and N. Schady (2009) 'Aggregate economic shocks, child schooling and child health', *The World Bank Research Observer* 24 (2): 147-181.

Glewwe, P. (1999) 'Why does mother's schooling raise child health in developing countries? Evidence from Morocco', *The Journal of Human Resources* 34 (1): 124-159.

Grimm, M. (2010) 'Mortality shocks and survivors' consumption growth', *Oxford Bulletin of Economics and Statistics* 72 (2): 146-171.

Haines, A., R.S. Kovats, D. Campbell-Lendrum and C. Corvalán (2006) 'Climate Change and Human Health: Impacts, Vulnerability, and Mitigation', *The Lancet* 367 (9528): 2101-2109.

Heltberg, R., N. Hossain, A. Reva and C. Turk (2012) 'Anatomy of coping. Evidence from people living through the crisis of 2008-11', *World Bank Policy Research Working Paper* 5957. Washington, DC: World Bank.

Heltberg, R. and N. Lund (2009) 'Shocks, coping, and outcomes for Pakistan's poor: Health risks predominate', *The Journal of Development Studies* 45 (6): 889-910.

Hoddinott, J. (1999) *Operationalizing household food security in development projects: an introduction*. Washington, DC: International Food Policy Research Institute.

Hoddinott, J. and B. Kinsey (2001) 'Child growth in the time of drought', *Oxford Bullettin of Economics and Statistics* 63 (4): 409-436.

Hsiang, S.M., M. Burke and E- Miguel (2013) 'Quantifying the influence of climate on human conflict', *Science* 341 (6151): 1235367.

IPCC (2001) *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

ISDR (2009) *Global Assessment Report on Disaster Risk Reduction*. Geneva, Switzerland: United Nations.

Kadiyala, S., A. Quisumbing, B. Rogers and P. Webb (2009) 'The impact of prime age adult mortality on child survival and growth in rural Ethiopia', *World Development* 37 (6): 1116-1128.

Kazianga H. and C. Udry (2006) 'Consumption Smoothing? Livestock, insurance and drought in rural Burkina Faso', *Journal of Development Economics* 79 (2): 413-446.

Kinsey, B., K. Burger and J.W. Gunning (1998) 'Coping with drought in Zimbabwe: Survey Evidence on Responses of Rural Households to Risk', *World Development* 26 (1): 89-110.

Lobell, D.B., M. Bänziger, C. Magorokosho and B. Vivek (2011) 'Nonlinear heat effects on African maize as evidenced by historical yield trials', *Nature and Climate Change* 1: 42-45.

Maccini, S.L. and D. Yang (2008) 'Under the weather: Health, schooling, and economic consequences of early-life rainfall', *NBER Working Papers Series* 14031. Cambridge, MA: NBER.

Mackinnon, J. (1995) 'Health as an informational good: the determinants of child nutrition and mortality during political and economic recovery in Uganda', *CSAE Working Paper Series* 95-9. Oxford, UK: Centre for the Study of African Economies.

Marini, A. and M. Gragnolati (2003) 'Malnutrition and poverty in Guatemala', *World Bank Policy Research Working Paper* 2967. Washington, DC: World Bank.

Martorell, R. (1999) 'The nature of child malnutrition and its long-term implications', *Food and Nutrition Bulletin* 20 (3): 288-92.

McMichael, A.J. and A. Haines (1997) 'Global Climate Change: The Potential Effects on Health', *British Medical Journal* 315 (7111): 805-809.

Mulder-Sibanda,M. (2011) *Senegal - Nutrition Enhancement Program II : P097181 - Implementation Status Results Report : Sequence 11*. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/2011/11/15451727/senegal-nutrition-enhancement-program-ii-p097181-implementation-status-results-report-sequence-11

Murdoch, J. (1995). 'Income smoothing and consumption smoothing', *Journal of Economic Perspectives* 9: 103-14.

Natalicchio, M. (2011) 'Senegal's fight against malnutrition: the Nutrition Enhancement Program', in Garrett, J. and M. Natalicchio (eds.) (2011) *Working multisectorally in nutrition. Principles, practices, and case studies.* Washington, DC: IFPRI.

Onis, M. de and M. Blössner (1997) *WHO Global Database on Child Growth and Malnutrition.* Geneva: World Health Organization, Programme on Nutrition. Available at <whqlibdoc.who.int/hq/1997/WHO_NUT_97.4.pdf>.

Paxson, C. and N. Schady (2005) 'Child health and economic crisis in Peru', *The World Bank Economic Review* 19 (2) : 203-223.

Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J. et al. (2010) 'The Impacts of Climate Change on Water Resources and Agriculture in China', *Nature* 467 (7311): 43-51.

Pongou, R., J. Salomon and M. Ezzati (2006) 'Health impacts of macroeconomic policies: determinants of variation in childhood malnutrition trends in Cameroon', *International Journal of Epidemiology* 35 (3): 648-656.

Quisumbing, A.R. (2003) 'Food aid and child nutrition in rural Ethiopia', *World Development* 31 (7): 1309-1324.

République du Sénégal (2010) *Analyse globale de la vulnerabilité, de la sicurité alimentaire et de la nutrition (AGVSAN).* Rome, Italy: World Food Programme.

Rosenzweig, M. and C. Udry (2013) 'Forecasting profitability', *NBER Working Paper* 19334. Cambridge, MA: National Bureau of Economic Research.

Sadoulet, E. and A. de Janvry (1995) *Quantitative Development Policy Analysis.* Baltimore MD: The Johns Hopkins University Press.

Senauer, B. and M. Garcia (1991) 'Determinants of the nutrition and health status of preschool children: an analysis with longitudinal data', *Economic Development and Cultural Change* 39 (2): 371-389.

Senne, J.-N. (2013) 'Death and schooling decisions over the short and long run in rural Madagascar', *Journal of Population Economics* 27 (2): 497-528.

Skoufias, E. and K. Vinha (2012) 'Climate variability and child height in rural Mexico', *Economics and Human Biology* 10: 54-73.

Singh, I., L. Squire and J. Strauss (1986) 'A Survey of Agricultural Household Models: Recent Findings and Policy Implications', *The World Bank Economic Review* 1 (1): 149-179.

Thomas, D. (1990) 'Intra-household resource allocation: an inferential approach', *The Journal of Human Resources* 25 (4): 635-664.

Thomas, D., J. Strauss and M.H. Henriques (1991) 'How does mother's education affect child height?', *The Journal of Human Resources* 26 (2): 183-211.

Thomas, D., V. Lavy and J. Strauss (1996) 'Public policy and anthropometric outcomes in the Cote d'Ivoire', *Journal of Public Economics* 61 (2): 155-192.

Townsend, R.M. (1994) 'Risk and insurance in village India', *Econometrica* 62 (3): 539-591.

Wagstaff, A. and M. Lindelow (2010) 'Are health shocks different? Evidence from a multi-shock survey in Laos', *Health Economics* (forthcoming).

WFP (2013) http://www.wfp.org/countries/senegal/overview

WHO and UNICEF (2009) *WHO child growth standards and the identification of severe acute malnutrition in infants and children. A joint statement by the World Health Organization and the United Nations Children's Fund.* Geneva, Switzerland, WHO Press. Available at <http://www.who.int/nutrition/publications/severemalnutrition/9789241598163_eng.pdf>.

World Bank (2013) World Bank Database. Accessed 30 August 2013 <http://data.worldbank.org/country/senegal>.

Yamano, T., H. Alderman and L. Christiaensen (2005) 'Child Growth, Shocks, and Food Aid in Rural Ethiopia', *American Journal of Agricultural Economics* 87(2): 273-288.

Yamauchi, F., Y. Yohannes and A. Quisumbing (2009) 'Natural disasters, self-insurance and human capital investment. Evidence from Bangladesh, Ethiopia and Malawi', *World Bank Policy Research Working Paper* 4910. Washington, DC: World Bank.

Yilma, Z., A. Mebratie, R. Sparrow, D. Abebaw, M. Dekker, G. Alemu and A.S. Bedi (2013) 'Coping with shocks in rural Ethiopia', *ISS Working Paper – General Series* n.560. The Hague, Netherlands: International Institute of Social Studies of the Erasmus University.

Chapter 5
Concluding remarks and policy implications

This thesis consists of three essays that explore the effects of natural disasters on welfare indicators at the macroeconomic and microeconomic level. Chapter 2 deals with the macroeconomic effects of natural disasters in terms of direct and indirect costs providing a systematization and meta-analysis of the emerging macro-econometric literature. Chapter 3 and 4 study the channels through which natural disasters, in terms of simple and complex extreme events, affect household welfare focusing on food consumption in Uganda and child weight-for-age in Senegal using a microeconometric approach. Note that Chapter 4 on child health in Senegal analyzes also non-natural shocks to account for the effects of concomitant natural and non-natural adverse events. In this concluding section I summarize the main findings and discuss some policy implications that emerge from the analyses conducted.

Although natural disasters have always affected societies around the world, the economic debate around the effects of natural disasters on the overall performance of the economies and on the lives of households and individuals in the developed and developing world has become most lively in the last decade. Chapter 2 deals with the macroeconomic evidence on the impact of natural disasters providing a systematization and meta-analysis of the emerging macroeconomic literature on direct and indirect (secondary) costs of natural hazards. This literature is nowadays highly developing, indeed a simple search through Google Scholar in 2014 (after Chapter 2 was written) returns few new published articles and many new working papers on the macroeconomics of natural disasters. A meta-analysis in a fast developing field of the economic research is extremely useful because it helps to disentangle the effects of methodological choices by the authors on the results. Moreover, it helps to assess if peer-reviewed literature is highlighting certain results, while emphasizing where the research has concentrated and unexplored areas in need of further attention. The results of the meta-analysis have important implications both in the formulation of policy-relevant documents such as the IPCC reports on natural extreme events, and policy makers' decisions concerning long-run prevention and mitigation investments based on macroeconomic evidence (Bergeijk and Lazzaroni, 2013).

As far as policy-relevant documents is concerned, a comparison with the literature review in the IPCC (2012) report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* may help to understand the strengths and weaknesses of meta-analysis in comparison with a traditional narrative literature review (Table 5.1).

Table 5.1 Strengths and weaknesses of meta-analysis and traditional literature review.

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

Source: van Bergeijk and Lazzaroni (2013), Table 8.

While the steps undertaken to produce the meta-analysis are listed and discussed in Chapter 2 and were accomplished within a limited amount of time, the IPCC Report is the result of a long and rigorous process. The IPCC process started in September 2008 with the proposal submission by the Norwegian government and the United Nations International Strategy for Disaster Reduction and ended in November 2011 at the IPCC Working Group I and II joint session. During the three years the drafts were subject to a double formal review of experts and governments leading to 18,784 comments. The author teams, accounting of about 250 authors[40], responded and/or followed up to every comment modifying the drafts in accordance with the available scientific knowledge (IPCC, 2012: xii). The Summary for Policymakers was evaluated and approved by consensus and on a line-by-line basis by delegates from more than 100 countries and the full report was accepted. Hence, the IPCC Report constitutes an outstanding example of multidisciplinary[41] and globally relevant research

[40] The authors were categorized according to their role: 87 Coordinating Lead Authors and Lead Authors, 19 Review Editors and 140 Contributing Authors that submitted draft text and information to the author teams.

[41] The Report combines the knowledge of scientific, technical and socio-economic disciplines to assess the state of the art and future developments in the field of climate change and disaster risk management. The global debate on the effects of climate change started in 1990 with the first IPCC scientific, impacts and response strategies assessments (IPCC, 1990a, 1990b, 1990c) and IPCC works have gradually become "the standard references for policy makers and

synthesis incorporating both qualitative and quantitative studies under the supervision of a very large group of authors. The broader scope of the IPCC Report is to assess the "scientific, technical and socioeconomic knowledge as of May 2011 […] [with] a strong commitment to assessing science in a way that is relevant to policy but not policy prescriptive" (IPCC, 2012: ix). This suggests that the report is presenting a traditional narrative review in order to infer generalizations about the effects of natural disasters, combining disaster risk reduction and climate change. Although the objective of the Report is explicitly non-policy prescriptive, the involvement of intrinsically political actors (governments, international organizations) occurred at least in two crucial stages of the review. First, author teams were nominated by governments and organizations such as the FAO or the World Bank[42] and approved by he IPCC Working Groups. Second, the report was subject to two rounds of revision, the second round involving also governments (IPCC, 2012: ix). This flow of actions and knowledge production within an iterative process combines different standpoints and perspectives on the research question. These competing positions include past and/or future political decisions on the macroeconomic management of natural disaster impact. Hence, they are likely to influence the implicit inclusion/exclusion criteria and the decision about what aspects of the literature to emphasize or undermine. By contrast, a meta-analysis is by design a transparent and objective tool to systematize the results in the literature and helps to better understand robustness of the results. Ultimately, the use of a meta-analysis in the Report would have added to the narrative literature review helping to infer *higher confidence* on the negative sign of the impact of natural disasters.

Similarly, if policy making has to be informed by research, having a tool like meta-analysis to help in the interpretation of competing results may potentially constitute a great advantage. This applies especially in the context of the elaboration of disaster preparedness and mitigation/adaptation measures involving huge investments over the long-tem. Often these decisions are based on cost-benefit analyses. However, the fat tails in the probability distribution of the likelihood of catastrophic event scenarios may undermine reliability of the results (Noy, 2012). Hence, cost-benefit analyses results could further be informed by macroeconometric results[43], the

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scientists" (IPCC, 2012: viii). The combination of traditional IPCC expertise with disaster risk reduction knowledge creates synergies and increases the value added of the Report.

[42] For a complete list of IPCC observers organizations the reader may refer to http://www.ipcc.ch/pdf/ipcc-principles/observers-as-of-june-2012.pdf, accessed 30 July 2013.

[43] For example, Hallegatte (2012) assesses the potential benefits from upgrading hydro meteorological information production and early warning capacity in all developing countries and finds that these measures could reduce asset losses between 300 million and 2 billion USD per year in developing countries, thus reducing disaster losses. According to

latter being evaluated in light of meta-analysis insights. This would provide stronger theoretical support to policy maker's decisions.

On the other hand, one of the drawbacks of the quantitative meta-analysis provided in Chapter 2 is that it excludes from the primary studies a complete set of literature (and results) on the effects of natural disasters. Stanley and Docouliagos (2012) propose to compare results of different strands of literature in qualitative fashion. However, they acknowledge that the variability in measurement of size of empirical effect often prevents a meaningful comparability of the reported results. It is precisely to allow maximum comparability that I decided to concentrate only on macro-econometric studies also separating studies on direct and indirect costs.

The meta-regression results suggest that the inclusion African countries in the analysis increases the probability to find a negative and significant impact of natural disasters in terms of disaster direct costs. When studies concentrate on disaster direct costs (effects on GDP growth/level), the inclusion of Africa does not significantly affect the reported disaster outcome. These results have been further investigated at the microeconomic level to understand the channels through which simple and complex extreme natural events affect household welfare. In Chapters 3 and 4 then I focused on two case studies from the African region considering, in the order, the effects of simple extreme events (weather variability) and the effects of complex extreme events (droughts) in concomitance with non-natural events (increasing purchasing prices).

Chapter 3 explores the effects of weather variability in terms of millimeters of rain, number of rainy days and minimum and maximum temperatures on rural households' food consumption expenditures in Uganda. The analysis is carried out relying on a partial-shock analysis using a dataset made publicly available by the World Bank Leaving Measurement Studies while qualitative interviews and the analysis of recent developments in the agricultural sector help to underpin the results, ultimately framing a mixed methods analysis. The results of the econometric model suggest that households in Uganda would be negatively affected by increases in maximum and minimum temperatures but they seem to be able to mitigate adverse variations of rainfall precipitation and distribution. Analyses of the overall household panel confirm the robustness of the results countrywide. Triangulating the findings of the econometric analysis with qualitative interviews and

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Hallegatte these benefits should increase with growth as in the the macro-econometric study by Toya and Skidmore (2007).

agricultural sector developments it is argued that rural households in Uganda would be involved in *ex-ante* income smoothing strategies (preference for staples production) that would help to partially offset the effects of weather variability. The ability to insure against rainfall and number of rainy days variations would depend also on land ownership and reduction of other expenditures such as those for social events and outgoing remittances. Some observations are worth making.

First, the literature on the effects of weather and climate variations on household welfare shows no consensus on the methods to operationalize weather and climate conditions. A limitation of the analysis in Chapter 3 is that it does not provide a sensitivity analysis of the results using different measures of weather variability. However, this is largely due to available weather data limitations.

Second, available meteorological data come from 13 synoptic station spread across the country. Given the high variability of weather, the analysis on the impact of rainfall and temperature variations would be more reliable if weather data were available on a lower scale. Besides my analysis, the availability of lower scale and more precise weather data (and forecasts) could help farmers and households in Uganda to take better production and consumption decisions. Indeed, James (2010) and Okonya et al. (2013) conducted a choice experiment and a survey in six sub counties and agro-ecological zones in Uganda to assess farmers' needs to improve adaptation. Both studies revealed farmers' need of more reliable forecasts on a daily basis. Moreover, since weather variability is very high throughout the seasons, farmers are increasingly demanding more accurate forecasts on a seasonal basis. This will allow them to better plan forthcoming season and investments (Osbahr et al., 2011). With this respect, the World Meteorological Organization and the Uganda Department of Meteorology have recently agreed on the *Severe Weather Forecasting Demonstration Project* (WMO, 2012) to develop a better system for better weather data recording and forecasting.

Third, although consumption data are generally used to measure household living standards, they have been proved to be particularly sensitive to changes in the survey design (method of recording, respondent level, length of the reference period and degree of detail in the commodity list) (Beegle et al., 2012). Hence the results of the econometric analysis have to be taken with some caution, while a field work in the areas covered by the LSMS dataset could be of help to further understand the channels through which weather variability has (or not) effects on households welfare, strengthening the findings of the overall analysis and results in Chapter 3.

Fourth, using mixed method the study of weather variability in Uganda in the period 2005-2010 has highlighted the progressive shift of agricultural production towards the cultivation of staples crops (rather than cash crops) as household strategy to insure food consumption from rainfall variability, leaving temperatures variability uninsured. The choice to use mixed methods is particularly relevant in the assessment of microeconomic impacts of certain phenomena because it allows more comprehensive interpretations of quantitative results, further contextualizing them. Besides, the result of the analysis has to be discussed in light of the National Development Plan (NDP). One of the objectives of the NDP is to develop strategic agricultural commodities. However, households preferences for low-risk, low-income staples in response to weather variations seem to leave too many Ugandans within subsistence agriculture, possibly perpetuating the poverty cycle. Formal public and private risk management strategies, such as the ones adopted by high income countries or emerging countries like Mexico and India could serve both to evade poverty traps stabilizing income and fostering adaptation (World Bank, 2005).

In general, governments can play an important role both *ex-ante* and *ex-post*. *Ex-ante*, potentiating education and services through agricultural extensions to increase awareness on the possible effects of increasing weather variability and warming while providing assistance in the adoption of measures to deal with them. Moreover, governments can provide infrastructures such as roads, dams and irrigation systems. These will favor timely interventions on cultivations and stored products to reduce losses in case of extreme events, and improve water management in time of scarcity/excess through water storage and rationing systems. As aforementioned, the Government of Uganda has been financing the National Agricultural Advisory Services program to increase the adoption of modern agricultural practices. However, the effectiveness is still low and the program needs to be strengthened in terms of farmers outreach throughout the country (Benin et al., 2007). *Ex-post*, governments can provide social assistance or create cash transfers schemes to provide relief. In Uganda, although the agricultural sector employs the bulk of the population, the persistent government under-investment in agriculture and wrong incentives (such as the 5% GDP ceiling to expenditures in agriculture and the tax-reduction on hoes) constitute major impediments to the adoption of high-technology inputs and modernization (Hickey, 2013: 202). This suggest that the Government of Uganda could play a more active role in the agricultural sector providing more effective formal risk management (extension services, social transfers and infrastructures) and better incentives (for example for the adoption of high yield and drought/heat resistant varieties).

On the other hand, market based mechanisms such as contract marketing, insurance and credit could enhance coping and adaptation capacities. Contract marketing helps to manage risk from price fluctuations through forward, futures and option contracts. Certainty of revenues and the related multiplier effects in the community, additional financing for informal risk management and backing-up for public interventions, and the potential extensions of output, storage, inputs and credit markets are some of the benefits of contract marketing (Larson et al., 2004). However, small farmers often cannot have access to contract marketing due to lack of assets and limited knowledge of the mechanisms, while incompleteness of most agricultural risk markets is a further obstacle. In Uganda coffee and cotton are the agricultural commodities for which internal and external marketing are at work since the 1990s. In the early days of cotton and coffee market liberalization cooperative unions were forced to sell to the private sector. Some of them survived and gradually engaged in contract marketing to provide minimum prices to farmers (Kang, 2005) but liberalized markets have substantially increased price volatility (Hill, 2010) and still contract marketing is an exception rather than the rule (World Bank, 2005).

Index insurance has been recently developing as a tool to manage weather-related production shortfalls in emerging economies such as India and Mexico (Hess, 2003; Skees et al., 2002). Index insurance relates payouts to observable weather indexes such as millimeters of rain in a specific location or to measured area-level yields. Major advantages are the provision of covariate risk management (uninsured under traditional risk sharing arrangements at the village level) and minimization of moral hazard and adverse selection (Giné et al., 2008). In particular, weather insurance has been rapidly developing in India where it now covers more than 9 million farmers insuring more than US $ 3.17 billion (Clarke et al., 2012). Weather insurance development in Uganda has been advocated as a potentially beneficial tool against environmental and economic shocks (Björkman-Nyqvist, 2013; Hegelson et al., 2012). A study for the viability of an index-based weather insurance program in Uganda is going to start in Uganda in 2014 by the International Finance Corporation – IFC thanks to a grant funded by the Global Index Insurance Facility – GIF and implemented by IFC and the World Bank (Ndungi, 2014). Note that in order to guarantee maximum adoption and benefits to farmers, weather insurance has to be appropriately designed. According to Giné et al. (2008) weather insurance has to have five characteristics: transparency and verifiability to farmers; non-manipulability of the index; the probability distribution of the index can be calculated; inexpensive and timely index measurement; correlation with household risk in terms of income and consumption. However, even when weather insurance is correctly designed many households might remain exposed to risk. Cole et al. (2013) conducted randomized experiments in two Indian states to assess the reasons for low adoption. High prices in comparison with payouts, lack of trust/understanding of the product, liquidity constraints (especially for poorer households with no access to credit) and salience seemed to be the main barriers to rainfall insurance adoption. Moreover, Cole et al. emphasized that "Triggers set in millimeters of rainfall are also alien to many farmers, as compared to familiar triggers for traditional indemnity policies, such as the death of an animal in the case of livestock insurance". Thus, the possible increase in farmers demand for new agricultural technologies rather than for weather insurance. In my view a combination of the two could provide a good mix to protect farmers from shocks *ex-ante* and *ex-post* also from different but concomitant shocks.

Fifth, the choice to consider the household as unit of analysis in Chapter 3 may understate heterogeneity of impacts of weather variability on the different household members, for example in terms of differential calories intake when food availability is lowered following adverse weather variations. Hence, policies to enhance consumption smoothing have to anticipate differential individual preferences within the household (Alderman et al., 1994) and differential impacts of extreme events on household members.

Chapter 4 conducts a multi-shock analysis particularly focusing on the effects of complex extreme events (droughts) and price shocks on weight-for-age of children in poor rural households in Senegal. Analyzing the impact of natural events considering their concomitance with other adverse events seems to be crucial in light of the several channels of effects at work. The results of the analysis show a negative impact of droughts and increasing price shocks on child weight-for-age. However, concomitance of the two shocks would generate positive income and food security effects allowing to protect child health in rural households (net food producers). The analysis in this chapter is still at the early stages in comparison with the one conducted in Chapter 2 and 3. The main conclusion that can be drawn however is that policy makers should carefully analyze the multiple channels through which shocks (and policy decision themselves) may affect household and individual welfare. In doing this they should also consider the effects of shock concomitance and interdependencies.

To conclude, as pointed out by early studies on the effects of natural disasters and more generally by studies on the effects of natural and non-natural shocks, both at the macroeconomic and microeconomic level these events are not negative as such but they are likely to trigger negative effects to the extent that the economy, households and individuals are not adequately prepared or are not involved in risk management activities that would allow prompt mitigation and recovery.

References

Alderman, H., L. Haddad, J. Hoddinott and S.A. Vosti (1994) 'Strengthening agricultural and natural resource policy through Intrahousehold analysis: an introduction', *American Journal of Agricultural Economics* 76 (5): 1208-1212.

Beegle, K., J. De Weerdt, J. Friedman and J. Gibson (2012) 'Methods of household consumption measurement through surveys: Experimental results from Tanzania', *Journal of Development Economics* 98: 3-18.

Benin, S., E. Nkonya, G. Okecho, J. Pender, S. Nahdy and S. Mugarura (2007) 'Assessing the Impact of the National Agricultural Advisory Services (NAADS) in the Uganda Rural Livelihoods', *IFPRI Discussion Paper No. 724*. Washington, DC: IFPRI.

Bergeijk, P.A.G. van and S. Lazzaroni (2013) 'Macroeconomics of Natural Disasters: Meta- analysis and Policy Options', Working Paper prepared for *Methods for Research Synthesis: A Cross-Disciplinary Workshop* (3-4 October). Cambridge, MA: Harvard Center for Risk Analysis.

Björkman-Nyqvist, M. (2013) 'Income shocks and gender gaps in education: evidence from Uganda', *Journal of Development Economics* 105: 237-253.

Clarke, D., O. Mahul, K.N. Rao and N. Verma (2012) 'Weather based crop insurance in India', *World Bank Policy Research Working Paper* 5985. Washington, DC: The World Bank.

Cole, S., X. Giné, J. Tobacman, P. Topalova, R. Townsend and J. Vickery (2013) 'Barriers to household risk management: evidence from India', *American Economic Journal: Applied Economics* 5 (1): 104-135.

Giné, X., R. Townsend and J. Vickery (2008) 'Patterns of rainfall insurance participation in rural India', *The World Bank Economic Review* 22 (3): 539-566.

Hallegatte, S. (2012) 'A cost effective solution to reduce disaster losses in developing countries: hydro meteorological services, early warning, and evacuation', Copenhagen Consensus Center Perspective Paper on Natural Disasters. Accessed 9 September 2013, available at <http://www.copenhagenconsensus.com/sites/default/files/Natural%2BDisasters_Perspective%2Bpaper%2B1.pdf>.

Hegelson, J., S. Dietz and S. Hochrainer-Stigler (2012) 'Vulnerability to weather disasters: the choice of coping strategies in rural Uganda', *Centre for Climate Change Economics and Policy Working Paper* 107. London, UK: Centre for Climate Change Economics and Policy, Grantham Research

Institute on Climate Change and the Environment, London School of Economics and Political Science.

Hess, Ulrich (2003) 'Innovative financial services for rural India', *Agriculture and Rural Development Working Paper* 9. Washington, DC: The World Bank, Agricultural and Rural Development Department.

Hickey, S. (2013) 'Beyond the Poverty Agenda? Insights from the New Politics of Development in Uganda', *World Development* 43 (3): 194-206.

Hill, R.V. (2010) 'Liberalization and producer price risk: examining subjective expectations in the Ugandan coffee market', *Journal of African Economies* 19 (4): 433-458.

IPCC (2012) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. (The SREX Report). Cambridge and New York: Cambridge University Press. Available at: <http://ipcc-wg2.gov/SREX/report/> Accessed 20 May 2013.

James, P.A.S. (2010) 'Using farmers' preferences to assess development policy: a case study of Uganda', *Development Policy Review* 28 (3): 359-378.

Kang, M.G. (2005) *An introduction to market-based instruments for agriculture price risk management*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Larson, D.F., J.R. Anderson and P. Varangis (2004) 'Policies on managing risk in agricultural markets', *The World Bank Research Observer* 19 (2): 199-230.

Ndungi, Ronald (2014) 'IFC to help insure 1 million EAC farmers in 2 years', EANANEWS Media for peace, stability and integration (8th February 2014). Accessed 10th February 2014, available at <http://eananews.org/1402281.htm> .

Noy, I. (2012) 'Investing in Disaster Risk Reduction: A Global Fund', Copenhagen Consensus Center Perspective Paper on Natural Disasters. Accessed 9 September 2013, available at <http://www.copenhagenconsensus.com/sites/default/files/Natural%2BDisasters_Perspective%2Bpaper%2BNoy.pdf>.

Okonya, J.S., K. Syndikus and J. Kroschel (2013) 'Farmers' perception of and coping strategies to climate change: evidence from six agro-ecological zones of Uganda', *Journal of Agricultural Science* 5 (8): 252-263.

Osbahr, H., P. Dorward, R. Stern and S. Cooper (2011) 'Supporting agricultural innovation in Uganda to respond to climate risk: linking climate change and variability with farmer perceptions', *Experimental Agriculture* 47 (2): 293-316.

Stanley, T.D. and H. Docouliagos (2012) Meta-regression analysis in economics and business. New York: Routledge.

Toya, H. and M. Skidmore (2007) 'Economic development and the impacts of natural disasters', *Economic Letters* 94: 20–25.

WMO (2012) *WMO Severe Weather Forecasting Demonstration Project (SWFDP) Mission to the Uganda Department of Meteorology*. Entebbe, Uganda: World Meteorological Organization. Available at < http://www.wmo.int/pages/prog/amp/pwsp/documents/Uganda_Final_Report.pdf>.

World Bank (2005) *Managing agricultural production risk*. Washington, DC: The World Bank., Agriculture and Rural Development Department.