# UNIVERSITA’ DEGLI STUDI DI PADOVA

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## CORSO DI LAUREA IN ECONOMIA

**PROVA FINALE**

# “NATURAL DISASTERS IN ITALY: EVOLUTION AND ECONOMIC IMPACT”

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# INDEX

# ABSTRACT

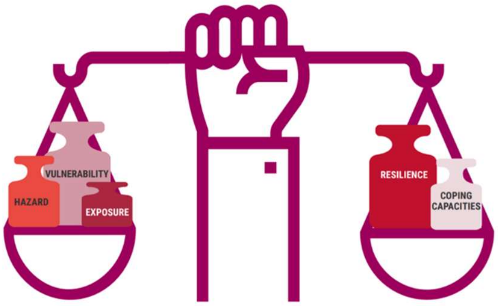
Negli ultimi anni, la consapevolezza riguardo l'impatto dei disastri naturali appare aumentata in maniera sostanziale. Tuttavia, se lo studio di tali fenomeni muove principalmente dalle scienze naturali, la ricerca in ambito economico risulta invece meno sviluppata (Kim 2010, p.2). L'economia dei disastri naturali si presenta come un ambito complesso, su cui insistono diversi fattori: il rischio intrinseco di un fenomeno, il grado di esposizione di una certa area (per caratteristiche geografiche o economico-sociali), la capacità di prevenzione e di reazione di fronte ad una calamità; tanto che l'impatto economico di uno stesso evento può risultare eterogeneo e di difficile previsione (Hallegatte e Przyluski 2010). In tale contesto, questo lavoro si propone di condurre un'analisi, a livello nazionale, sull'evoluzione e l'impatto economico dei disastri naturali dal secondo dopoguerra ad oggi in Italia, focalizzando l'attenzione sugli ultimi tre grandi terremoti occorsi: in Abruzzo (2009), Emilia (2012) e in tutta l'Italia Centrale (2016). In tutto il periodo considerato, l'Italia è stata colpita da quasi centocinquanta eventi disastrosi di natura molteplice che, seppur distribuitisi in maniera variabile nel corso degli anni, hanno fatto registrare nell'ultimo decennio valori medi quasi otto volte più alti, rispetto a settant'anni fa. Si stima che, per far fronte a tali eventi, siano state stanziate risorse pubbliche per un importo totale superiore ai 300 miliardi di € (ai prezzi del 2018), di cui per metà concentrate sui sette eventi più disastrosi, tutti terremoti. Di questi, gli ultimi tre (sopra citati) hanno avuto un peso complessivo per più di 40 miliardi, più di quanto si stima sia necessario per mettere in sicurezza le abitazioni in tutte le zone del territorio nazionale ad alto rischio sismico. Con riguardo a questi tre eventi, è stata quindi condotta un'analisi dell'impatto dei terremoti e degli aiuti pubblici che ne seguono, a livello comunale. Sfruttando lo scenario quasi-sperimentale offerto dai sismi, attraverso un approccio econometrico *difference-in-difference,* sono stati utilizzati i dati pubblici sulle dichiarazioni dei redditi per stimare il differenziale atteso nella variazione dell'output pre-post terremoto, tra comuni colpiti e non colpiti. Tale differenziale risulta generalmente positivo in Abruzzo ed Emilia, dove vi è stata un'allocazione tempestiva dei fondi per la ricostruzione. Le indicazioni non sono altrettanto nette per il terremoto in Italia Centrale, dove all'estensione territoriale più ampia sono associati stanziamenti pubblici iniziali più focalizzati sul breve periodo. La riduzione, attraverso interventi preventivi, dell'impatto notevole di eventi disastrosi quali i terremoti, dovrebbe essere di primario interesse per i *policy-maker*, tanto più considerando come l'incidenza di altri eventi, principalmente climatici e meteorologici, abbia mostrato una crescita sostenuta nel corso degli anni, tale da poter porre nei prossimi decenni un'ulteriore pressione non solo sulle finanze pubbliche, ma anche sugli equilibri socio-economici di vaste aree del territorio nazionale.

# INTRODUCTION

In the last few decades, general awareness about natural disasters has significantly increased worldwide: the widespread coverage of media, broadcasts ever more frequently warning calls on deaths, infrastructural and economic damages due to natural disasters, mainly in densely-populated hazard-exposed areas, in industrializing and industrialized countries. Alongside this, climate and environmental-related issues, which used to be faced as long-term problems, are turning out having considerable implications even within shorter timeframes. Indeed, natural disasters appear to be spreading in several directions: on one hand, regions historically exposed to extreme events (storms, cyclones or heavy rains), seem to be affected harder and within shortened return periods than in the past (World Bank and United Nations 2010); on the other, the incidence of phenomena, not peculiar of certain climatic regions are significantly rising (Field et al. 2012) ("off-season" heat waves, protracted droughts, frequent storms, …). In addition, the occurrence of other non-climate deterministic shocks, as earthquakes, volcanic eruptions or natural floods, is increasingly amplified by global population rising and urban density growth in highly hazard-exposed areas. By their nature, this kind of events still results, short-term, in even more catastrophic disasters than the aforementioned ones, in terms of immediate capital stock destruction and human casualties they produce (*§1.5; §2.2*).

Disasters risk evaluation is a complex task for policy-makers, as it is determined by the concurrence of multiple factors (UNDRR 2019, pp.18-19) (*Fig.1)*: *Disaster Risk* can be defined as "the potential loss of life, injury or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time" , and can be expressed as a probabilistic function of, on one side, *hazard* (the phenomenon itself), *exposure* ("the localization of people, infrastructure, housing, production capacities and other tangible human assets […]") and *vulnerability* ("conditions related to physical, social, economic and environmental factors or processes which determine or increase the susceptibility of a community or a set of assets […] "); on the other of *coping capacity* ("the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions […]") and *resilience* ("the ability of a system, community or society that is exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner

DISASTER RISK (Fig.1)



(source: UNDRR *2019,* © Shutterstock)

[…]”). In terms of damages and losses, a disaster might be larger or smaller depending on the frequency of *hazards*, the width of *exposure*, the level of *vulnerability* (Ratti 2017, p.7). It is then clear that potential damages arising from natural disasters, are not only determined by the contingent nature of hazards, but are heterogeneous, region-specific and determined by a range of different influences, among which local economic structures and development, together with political and social conditions, play a primary role.

In this articulated framework, figures show the number of natural disasters worldwide having more than doubled from the late-eighties, but economic damages having almost tripled (Ritchie and Roser 2019). Therefore, it is not surprising that the perception of the relevance of economic and social damages arising from natural disasters has significantly grown (Blaikie et al. 2014, see Marin and Modica 2017, p.57).

However, as pointed out by Kim (2010, p.2), the economics of natural disasters is still a nascent field: economic research on the consequences of natural disasters is still fairly limited, particularly with respect to natural sciences field.

In this context, this work aims at undertaking a country-level analysis, focusing on natural disasters evolution and economic impact in Italy, one of the European countries which suffered major losses from natural disasters in the last forty years (European Environment Agency 2019). If research has already been carried out on mapping socio-economic exposure to natural hazards from an *ex-ante* perspective, even at a municipal level (Marin and Modica 2017), the objective here is to contribute from an *ex-post* angle, to refine the drafting of a complete database of natural disasters occurred in Italy from the Second World War to present, and to establish a unitary analysis of their impact on public finances. Moreover, even though natural disasters may have disruptive effects on local economies, these tend to be difficultly observable through annual economic indicators at national (but even provincial) level (Porcelli and Trezzi 2014). What will be done, therefore, is to try and introduce, through a simple analysis, some empirical estimates at a micro-municipal level of the economic impact of disasters and subsequent public authorities’ interventions, with a short-run focus.

In the first part, after a general contextualization of the concept of natural disaster with a focus on its *economic* consequences, an analysis of natural disasters evolution in Italy will be undertaken. The second part will sum up the research work carried out in reconstructing how disasters-related public spending evolved, with a final focus on the interventions that followed the three major disasters (earthquakes) in recent Italian history*: Abruzzo (2009), Emilia (2012), Central Italy (2016)*. The third part will undertake an empirical analysis of the economic impact of the three aforementioned earthquakes, at a micro-municipal level.

# CHAPTER 1: NATURAL DISASTERS: CONCEPTS, *ECONOMICS* AND EVOLUTION IN ITALY

## 1.1 CONCEPTS

It might be useful to start with some terminological clarification on natural disaster concept. From a qualitative point of view, it is difficult to formulate one exhaustive definition, as the perception of events as natural disasters may be influenced by the socio-economic context in which they occur: concurrence of natural hazards and human actions, spatial and temporal extent, kind and magnitude of damages might be diversely conceived in different settings (Ratti 2017). A qualitative characterization has therefore to transcend precise definitions of causes or kind of damages, but might rather establish the broad nature of break induced by shocks. In this context it is possible to place UNISDR's definition (see Ratti 2017, p.6), according to which a (natural) hazard turns into a disaster, if it results in serious *disruptive effects* on the life of affected communities, considering human, material, environmental and economic losses, such that they are not able to recover through their own resources only. If the effects end up being unrecoverable as to pre-existing conditions, the disaster might turn into a *catastrophe* (Posner 2004, see Ratti 2017, p.6). From an economic point of view, Hallegatte and Przyluski (2010, p.2) essentially consider natural disasters as any natural shock affecting an economic system, resulting in significantly negative consequences for firms' assets and production factors, for consumption dynamics and labor market conditions.

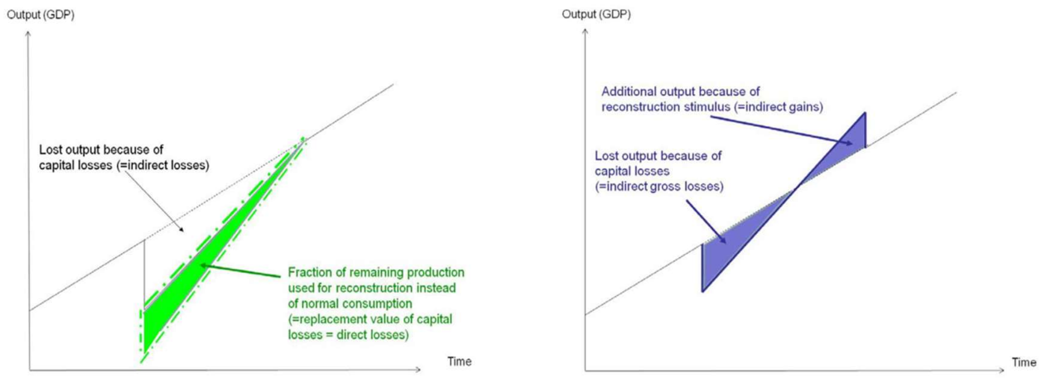
Alternatively, or complementarily, natural disasters might be defined in terms of quantitative thresholds (deaths, injured people, direct damages, …). Although this alternative might result restricting or might still lead to conflicting results depending on thresholds choice, it provides a more objective basis, making it more suitable for empirical analyses. This methodology is therefore the one that will be mainly adopted in the continuation of this chapter.

## 1.2 THE *ECONOMICS*

To complete the theoretical framework, the main economic concepts in natural disasters analysis will be explored further; the work of Hallegatte and Przyluski (2010) provides an exhaustive overview. Essentially, natural disasters tend to affect the economic system in several ways (*§1.1*). However, damages can be traced back into two broad macro-categories: direct and indirect losses. The former comprehends all immediate physical consequences, and can be divided into market losses (such as the destruction of tangible assets), referring to losses of tradable goods easily computable from market prices, and non-market losses (as damages to ecosystems or life losses) which cannot be traded or replaced, posing wider problems in terms of monetary quantification. The latter refers to secondary effects, not caused by the disaster itself, but by its consequences (as increases in unemployment, business failures, tourists' flows reduction, …). In principle, indirect losses should include all those costs that transcend temporal and spatial boundaries of the disaster itself, or that derive from losses in economic sectors different from those directly damaged. It is important to point out that indirect losses can generate "negative costs" as well (relative "gains"). That is, for example, any stimulus created by reconstruction activities.

Having identified potential sources of economic losses, it is fundamental, to conduct any economic evaluation, to define a proper counterfactual (*what would the economic trajectory have been, if the disaster did not happen?*). Estimates of economic costs can get furthermore complicated if post-disaster economy does not return to the hypothesized baseline-scenario, in case of permanent negative, or even positive effects. This might be the case when reconstruction enhances the expansion of certain economic sectors, or the adoption of more advanced technologies.

THE *ECONOMICS* OF NATURAL DISASTERS (Fig.2)


(a)

(b)

(source: Hallegatte and Przyluski, *The Economics of Natural Disasters: Concepts and Methods,* 2010, World Bank)

Depending on the *flexibility* of production systems, output losses might be compensated or not by the reconstruction process in the short-term. In a system with no flexibility (where the production level is saturated) part of the unaffected capital in production has to be diverted to reconstruction, thus observable output reduction might not be cushioned (*Fig.2(a)*). Contrarily, if it is possible to increase the productivity of unaffected capital (i.e. increasing hours worked) for reconstruction processes, there might then be a limited diversion of resources from production. As a result, output losses might be reduced, or even more than compensated by the reconstruction stimulus (*Fig.2(b)*).

Among available global natural disasters databases, Hallegatte and Przyluski (2010) indicate the *Emergency Events Database*, EM-DAT, (Université Catholique de Louvain-CRED 2019), as an important source of publicly available data.

## 1.3 THE EMERGENCY EVENTS DATABASE

The *Emergency Events Database,* created in 1988 to support the WHO in disaster risk management and prevention, records over 22,000 natural disasters worldwide from 1900 to present days. Major sources are UN agencies, NGOs, research institutions, insurance companies and press agencies. The database contains both natural (*Tab.1*) and technological disasters, classified as follows:

**NATURAL DISASTERS (Tab.1)**

| *disaster soubgroup* | *description* | *Dysasters main types* |
|---|---|---|
| Geophysical | A hazard originating from solid earth. This term is used interchangeably with the term geological hazard | Earthquake<br>Mass Movement (dry)<br>Volcanic activity |
| Meteorological | A hazard caused by short-lived, micro- to meso-scale extreme weather and atmospheric conditions that last from minutes to days. | Extreme Temperature<br>Fog<br>Storm |
| Hydrological | A hazard caused by the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater. | Flood<br>Landslide<br>Wave action |
| Climatological | A hazard caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability. | Drought<br>Glacial Lake Outburst<br>WIldfire |
| Biological | A hazard caused by the exposure to living organisms and their toxic substances (e.g. venom, mold) or vector-borne diseases that they may carry. Examples are venomous wildlife and insects, poisonous plants, and mosquitoes carrying disease-causing agents such as parasites, bacteria, or viruses (e.g. malaria). | Epidemic<br>Insect Infestation<br>Animal Accident |
| Extraterrestrial | A hazard caused by asteroids, meteoroids, and comets as they pass near-earth, enter the Earth's atmosphere, and/or strike the Earth, and by changes in interplanetary conditions that effect the Earth's magnetosphere, ionosphere, and thermosphere | Impact<br>Space weather |

(source: UNIVERSITE CATHOLIQUE DE LOUVAIN– CRED, 2019. *Em-Dat: The Emergency Events Database*)

Technological disasters include: Industrial Accidents, Transport Accidents and Miscellaneous Accidents. For a disaster to be entered into the database at least one of the following criteria must be fulfilled:

- Ten or more people reported killed;
- Hundred or more people reported affected;
- Declaration of a state of emergency;
- Call for international assistance.

Each disaster is identified by a univocal code consisting of the year of occurrence, and a progressive number (e.g. “1997-0327”).

### 1.4 SETTING UP A DATABASE FOR ITALY (1944 – 2018)

From the *Emergency Events Database* is possible to extract data for disasters occurred in the Italian territory. Only natural disasters are included in this analysis (excluding technological ones), for an initial total of 152 events. However, some events are excluded:

- Observation between 1905 and 1943: very few (eight) events, not precisely specified and with no possibility of cross-checking information;
- *Biological disasters*: only account for two registrations in the early ’00 in Southern Italy (no other significant information available);
- *Wildfires*: seven events recorded only in recent years. Moreover, it was not possible to discriminate between arsons and real wildfires;
- Two other events were excluded because of the impossibility to find any information on them; database providers were not able to supply additional relevant details (“*1999-0022*”: landslide in January, “*1997-0278*”: storm in November);
- For *Emilia* (2012) earthquake, two separate registrations (*2012-0142* and *2012-0162*) were included for two tremors on the 20th and 26th of May. Information were aggregated under one single code (*2012-0142*).

A preliminary analysis of data posed concerns about the precision of records farther in time: older observations are in fact much less precisely recorded (as to location, date and size), as other authors also pointed out (Ratti 2017; Hallegatte and Przyluski 2010). According to this consideration, EM-DAT observation were therefore cross-checked with information contained in an Italian report, jointly redacted by the *National Builders Association* and the *Center of Socio-Economic Research in Construction* (ANCE and CRESME 2012), published by the Italian Chamber of Deputies, which contains a detailed list of natural events occurred in Italy between 1944 and 1990 (pp.145–150). From this document, it was possible to extract seventeen more natural disasters, aligned to EM-DAT criteria, but not included in it: seven earthquakes, six floods, three landslides and one storm. A unitary database was then created including events from both sources. A different identification code was assigned to added events (e.g. “1C”). All events not clearly registered as to dates or localization, were cross-checked within multiple sources:

- National Centers for Environmental Information (NOAA s.d.);
- *Sistema Informativo sulle Catastrofi Idrogeologiche* (IRPI s.d.)*;*
- *Bollettino Siccità* (ISPRA s.d.).

The final list contains 149 natural disasters occurred between 1944 and 2018, divided by macro-areas (North, Center, South-Islands) and macro-categories (geophysical, hydrological, climate-meteorological). Data were also organized on a regional (380 data points) and, when possible, provincial basis (459).

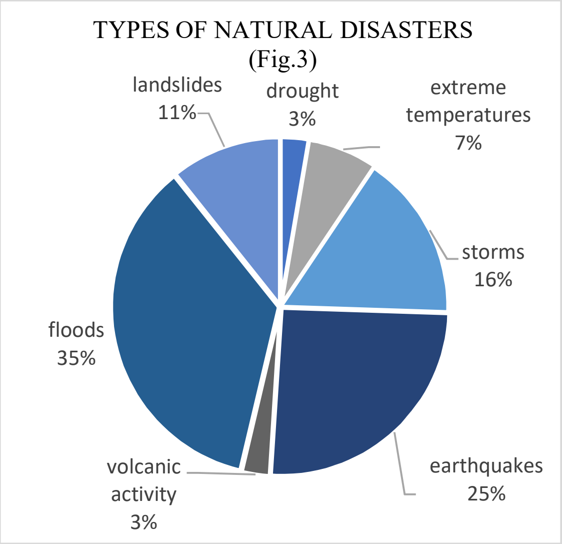
## 1.5 EVOLUTION OF NATURAL DISASTERS IN ITALY

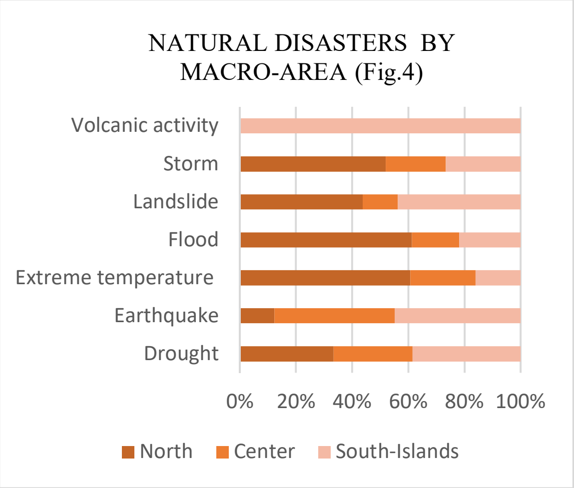
From the World War II onward, 149 ascertained natural disasters took place. Among these, almost one-half (sixty-nine) are hydrological (floods, landslides), geophysical (earthquakes, volcanic activities) ones account for forty-two, while climate-meteorological (storms, extreme temperatures, drought) are thirty-eight.

Floods are the most frequent disasters (*Fig.3*), accounting for 35% of total, with particular incidence in Northern areas (*Fig.4*), affecting almost three million people and causing around one-thousand deaths. This kind of disaster is particularly calamitous when it happens to hit major cities, as happened in Florence (1966) or Genova (1970). Second in terms of frequency (25%), but first in terms of deaths, are earthquakes, killing 7400 people over the last seventy-five years.

Italy is, together with Greece, the most exposed country in Europe in terms of seismic hazard; Italian history is dense of earthquakes which have left profound wounds in the socio-economic fabric.

Among these, the ones in Belice (1968), Friuli (1976), Irpinia (1980), Abruzzo (2009), Central Italy (2016) were the most catastrophic as to deaths, accounting for 87% of total earthquakes victims. Earthquakes hit mainly Central-Southern areas, with a particular concentration in Apennine regions (rarer, but not less harmful, are earthquakes in the North).


TYPES OF NATURAL DISASTERS (Fig.3)

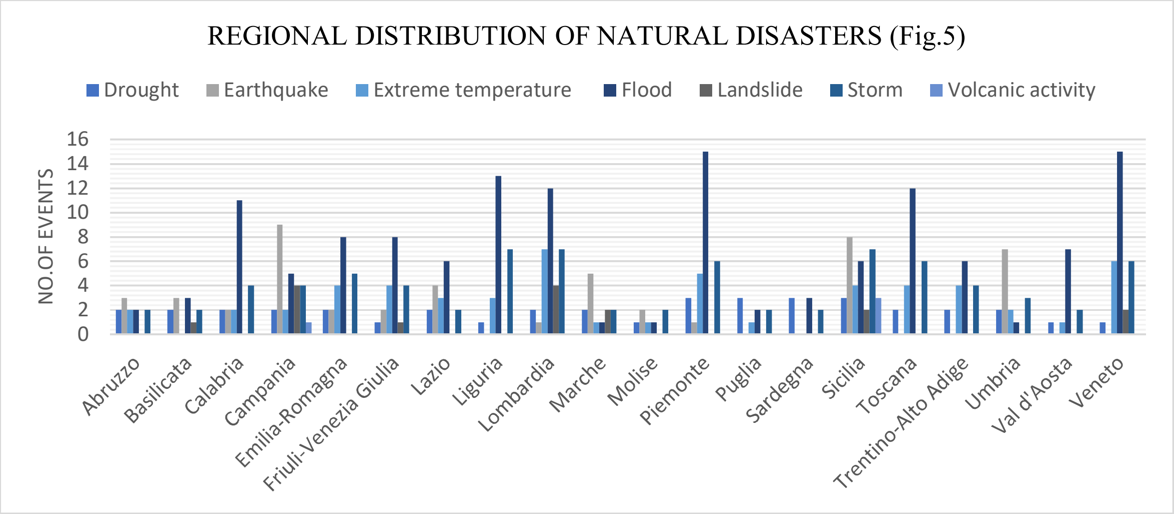


The third cause of natural disasters are storms, with an incidence of 16%, affecting indistinctly from North to South. Contrarily to earthquakes or floods, which tend to be localized events, storms usually have a vast extension covering frequently more than one region: in the last ten years, six disastrous storms involved on average the surface of more than five regions. In contrast, only three storms were registered over the decade before. Landslides account for 11% and, as extreme temperatures (7%), tend to cover the entire national soil. If landslides mirror the historical fragility of the Italian territory, dreadful waves of extreme temperatures (both hot and cold) are quite a recent phenomenon: the first registration is in fact in the late-nineties. Since then, extreme-temperature events have increased in their frequency and in their extension. Residual fractions are represented by droughts and volcanic activity, both at 3%. As extreme temperatures, extreme droughts have been registered only from the late-nineties and the last two events covered almost all the National territory.

A low frequency of events, such as extreme temperatures or intense drought periods, should not lead to and underestimation of the weight of this kind of hazards. Leaving aside here the awareness of this kind of events farther in time (and therefore registrations precision), they would seem here to be scaled back. This might be attributable to the threshold choice by EM-DAT authors (*§1.3*) which, although crucial to conduct an objective categorization of events (*§1.1*), results in concealing *under the radar* events that, although strictly speaking are not disasters in the short-run, might potentially assume catastrophic connotations over medium-long terms.

A last note on volcanic activity: registrations are not frequent (3%) and homogenously distributed. These events, that affect Southern Italy only (Etna and Vesuvio Volcanoes) concern mainly because of the steady urbanization of wide areas exposed to volcanic risk. Italy is one of the first countries in the world as to number of inhabitants exposed to volcanic risk (Gatti 2012). Over 700,000 people live in the “red zone” of mt. Vesuvio (La Repubblica 2018): unforeseen violent eruptions, although very unlikely, would provoke unimaginable consequences.

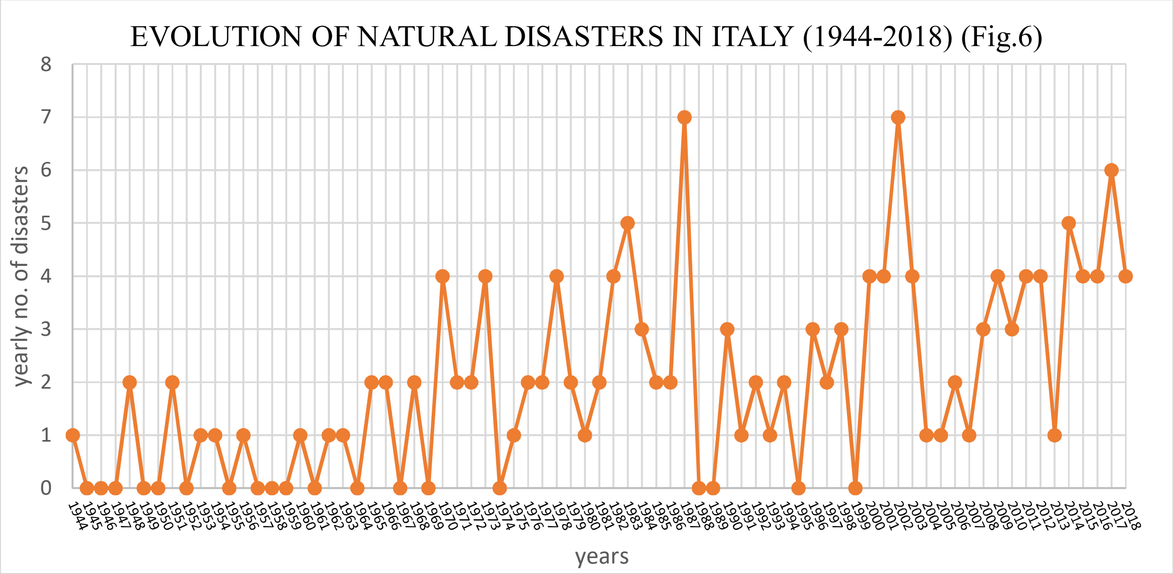
At a regional level (*Fig.5*), Lombardy and Sicily were the most affected areas with 33 natural disasters, followed at 30 by Veneto and Piemonte. If Sicily was mainly stricken by earthquakes, all northern regions suffered instead from a higher incidence of floods, which roughly accounted for one half of total disasters.


REGIONAL DISTRIBUTION OF NATURAL DISASTERS (Fig.5)

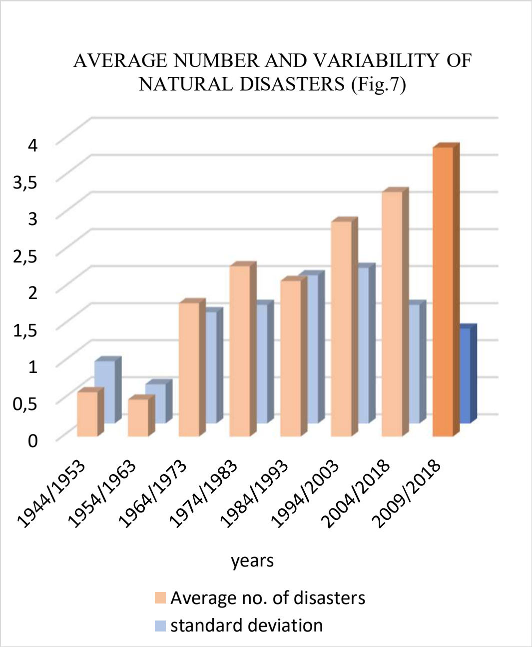
However, normalizing the number of events for regions sizes, Liguria results being the most affected region, with 4.43 disasters per thousand squared-kilometers, where floods and storms accounted for more than 80% of disasters. In terms of deaths, 86 every 100,000 inhabitants were killed in Northern regions, while figures are lower in Southern-Insular and Central Italy with respectively 66 and 11 deaths per 100,000 inhabitants. As to regional patterns, Northern regions are mainly subject to hydrological events and in central ones spikes up the incidence of earthquakes, southern regions have instead more heterogeneous patterns: Sicily and Campania, for example, were indistinctly hit by all disaster's categories considered, while in Calabria figures peak in hydrological ones, similarly to the North.

At a provincial level, some territories tended to be hit more repetitively than others. Most affected areas were also those where large metropolitan cities are: Naples and Venice (12 events), Genova (11), Turin (10), Milan (9), Rome (8), thus highlighting how population density in restricted areas plays a non-negligible role in switching natural hazards into disasters.

An overview of the complete series (*Fig.6*), leads to a conclusive question: what was the evolution of natural disasters over time?

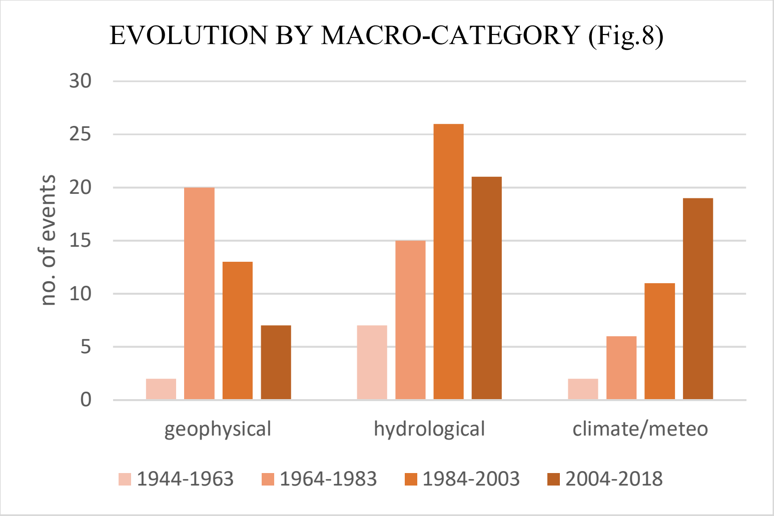

EVOLUTION OF NATURAL DISASTERS IN ITALY (1944-2018) (Fig.6)

A first look at the chart does not seem to suggest any clear trend, but data present wide variability. As also pointed out by Hallegatte and Przyluski (2010), data on large natural disasters are scarce, because of their nature of, fortunately, rare events. If this does not allow for a large sample necessary for econometric analysis, it is still possible to look at some descriptive statistics to extract valuable insights. Looking at ten-year means (*Fig. 7*), from 1944 to the mid-sixties, around one natural disaster every two years occurred. During the sixties, figures grew at 1.8 disaster per year, remaining then stable between 2.3 and 2.1 for the two following decades. Between the late-nineties and the beginning of the new century, figures underwent a steep rise to 2.9 per year, attesting at an even higher yearly average level of 3.9 from 2009 to present days. This growing trend is not immediately identifiable due to high annual variability, which indeed is not constant during the period. In terms of decennial standard deviations, this is relatively low during initial decades (0.84 in the period 1944-1953, 0.53 for 1954-1963), increasing then from the late sixties to the late nineties to more than 2.1, decreasing thereafter to 1.28 over the last decade. That is, if after the WW II data were quite less variable around low values, after a period of


AVERAGE NUMBER AND VARIABILITY OF NATURAL DISASTERS (Fig.7)

higher variability at the end of the century, figures seem having settled around higher levels in recent years.

In terms of macro-categories (*Fig.8*), geophysical disasters grew between the sixties and early-eighties falling afterwards (thanks probably to the establishment of an anti-seismic legislation in the construction sector *(§2.2*), whereas hydrological ones grew until the end of the century and stabilized thereafter. Climate-meteorological disasters showed, instead, a continuous growth: only two were registered until 1963, growing at 6 during the following twenty years, 11 between 1984 and 2003, 19 in the last fifteen years.


EVOLUTION BY MACRO-CATEGORY (Fig.8)

Although, as stated before, no aim of inference or forecast would make sense in this context, it is worthwhile to highlight that, due to the manifold possible contributory causes described in previous paragraphs, the frequency of natural disasters, despite annual variability, seems to be stabilizing around higher average levels than in the past. Among macro-categories analyzed, climate-meteorological disasters seem to be growing faster than others in recent years.

# CHAPTER 2: NATURAL DISASTERS AND PUBLIC SPENDING IN ITALY

The descriptive analysis presented in the previous chapter does not tell much regarding the intensity of events as to economic losses (once conditions for inclusion in the database are satisfied, no weight is given for the magnitude of events). However, in terms of economic impact, natural disasters might differ among categories, and over time. The following analysis aims at investigating how expenditures evolved, and whether it is possible to identify any common ground with the frequency evolution (*§1.5*). The EM-DAT *(§1.3)* provides some estimates of disasters damages, however data are not available for all the events (59 missing). Moreover, as reported in the explanatory notes to the database and by Hallegatte and Przyluski (2010, p.28), figures only account for immediate direct losses. That is, the immediate damage estimated at the moment of the event. This is why these data do not appear useful to estimate the overall economic impact.

Italy, contrarily to other European countries (Boccard 2008), does not have an insurance scheme for natural hazards. It follows that a very small risk portion is covered by private insurances, and insurance penetration in this field is among the lowest in the industrialized countries (Swiss Re 2018). As a result, the Italian Government has always acted as an *insurer of last resort*, fully financing rebuilding programs and supporting interrupted economic activities. That said, it seems justified to choose public spending as an indicator for overall economic costs.

## 2.1 DATA COLLECTION

A detailed analysis of public spending in Italy, requires the integration of data from different sources, covering different time periods. The objective is to identify the evolution of budgetary allocations from 1944 to present days. The two main sources are:

- *Primo Rapporto ANCE/CRESME – Lo stato del territorio italiano* (2012);
- Italian Government Budget Documents.

The first document covers all provisions from 1944 to 2009. Specifically included are geophysical (earthquakes, volcanic activity) and hydrological events (floods, landslides), which constitute almost the totality of the Italian effort in natural hazards financial exposure (Swiss Re 2018). General references regarding expenses for *all other disastrous events* are also given. Total expenditures are estimated harmonizing different provisions distributed on a 65-year time, at 2011 ISTAT Price Index.

Total expenses, expressed in €2011, attested at around 222 billion: 168 of which were devoted to earthquakes, 54 to hydrogeological disasters. As pointed out in the report (ANCE and CRESME 2012, p.141), these sums account not only for initial budget allocations necessary to face immediate emergencies management, for first aid interventions and for short term needs of affected populations, but also for funds devoted to the subsequent reconstruction of infrastructures and of the damaged or destroyed, public and private building stock. Moreover, support grants for interrupted economic activities (to ensure their viability and recovery) are also included, together with charges resulting from tax credits, tax cuts and reductions in contributions to affected firms and private citizens. Of €168 billion earmarked for geophysical calamities, 99 billion refer to the period from 1944 to 1990. Considering instead those for hydrological events, 31 billion over 54 were allocated up to 1990, 23 billion from 1991 onward. Estimated €2 more billion, are added to these sums, including all other disastrous events.

Allocations from 1944 to 1990 are catalogued thanks to the work of Catenacci (see ANCE and CRESME 2012, pp.145-150), a geologist who filled a detailed listing of natural disasters ordered by category, date and place of occurrence, together with amounts and durations of all the corresponding funding instalments from the Central Government. Reported data from 1991 to 2009 refer, instead, to a publication of Geologists' National Council (CNG 2010).

These two sets of data were reorganized shifting from an event-based classification to a yearly amortization (as they would appear in yearly Government Budgets). Public funds from 1944 to 1990 were easily handed out, as starting years and length of each instalment was explicitly indicated. Allocations covering more than one year, when specific indications were absent, were assumed to be equally distributed over the funding period. Funds from 1991 to 2009 were precisely amortized whenever reference to specific provisions of law were available (CNG 2010, ch.7 pp.15 e ss.). Residual funds were equally distributed over the period.

To complete the series from 2007 to present, official publicly available documents from the Italian Government Budget were examined. From these documents it is possible to secure detailed data on expenditures for natural disasters. Extracted cost items are the same as those included in ANCE and CRESME Report (2012), summarized in the previous page. Moreover, to keep data homogeneous, for each year were only considered appropriations of competence of that year (and not cash appropriations, for which no information is available in the series prior to 2007).

National Budget documents are organized according to *Missions, Programs and Actions* (in ascending order of disaggregation). *Missions* represent principal expenditure functions and strategic objectives pursued; *Programs* are homogeneous expenditure aggregates for the achievement of objectives defined by *Missions* in which they are included; *Actions* are budget aggregates underlying expenditure programs, specified for a better understanding and verifiability of funding allocations (Ragioneria Generale dello Stato 2019).

Documents from 2007 to 2010 are available at a disaggregated level up to *Programs* (but not *Actions*) (Ragioneria Generale dello Stato 2018). The considered mission for this period is *Civil Rescue,* which includes appropriations from the Ministry of Economic Affairs and Finance for the programs *Interventions for Public Calamities* and *Civil Defense* and from the Ministry of the Interior for the program *Risk Prevention and Public Aid*. As no other mission includes relevant expenditure items for this period, Civil Rescue is assumed to be in this case a good proxy of the overall economic impact on public finances. From 2011 onward, expenditure items are distributed also within other missions and/or ministries. However, from the same year, *Technical Annexes* to the State Financial Budget ("*Allegato Tecnico – Disegno di Legge di Bilancio*") are available for every single Ministry (Ragioneria Generale dello Stato 2011; 2012; 2013; 2014; 2015; 2016; 2017; 2018b; 2019b). In these documents, expenditure items are disaggregated up to every single *Action.* It is therefore possible to extract, year by year, Ministry by Ministry, allocations of competence just for natural disasters.

Budget allocations to *Civil Rescue* mission fall between 2010 and 2011 (from around €5.7 billion to €4.2 billion at current prices, gradually increasing thereafter up to €6 billion in 2019). In parallel, this decrease is compensated by growth in other missions. Under the Ministry of Economic Affairs and Finance, which holds the majority of total allocations, other relevant programs emerge: *Support measures through the tax system* account for €5.14 billion allocated from 2011 to 2019, €1.7 billion are allocated for *Reimbursements to local authorities*, €4.1 billion for *Residential constructions*, and €1.24 billion for *Debt burdens* arising from natural disasters not already included in *Civil Rescue* mission*.* At current prices, the Ministry of Economic Affairs has totally allocated between 2007 and 2019 (including expenditure forecasts for 2020 and 2021), around €54.23 billion, followed by the Ministry of the Interior with €32.7 billion. Within the latter, the majority (€32.3 billion) refer to *Civil Rescue,* whereas €0.4 residual billion are allocated to multiple specific actions. The Ministry of Infrastructures accounts for €3.7 billion from 2011 onward; the largest part of these funds was allocated to floods prevention in Venice area (almost €3 billion). Allocations at the Ministry of Economic Development account for €1.35 billion, (mostly concentrated in one expenditure item, in 2014, for the earthquake occurred in Abruzzo (2009), for €0.91 billion) and for €1.73 billion at the

Ministry of the Environment and Territory Protection. The latter mainly refer to prevention interventions and are allocated for more than one billion from 2017 onward. Residual funds pertain to the Ministry of Labor and Ministry of Cultural Heritage, for €0.15 billion in total.

## 2.2 THE COMPLETE SERIES

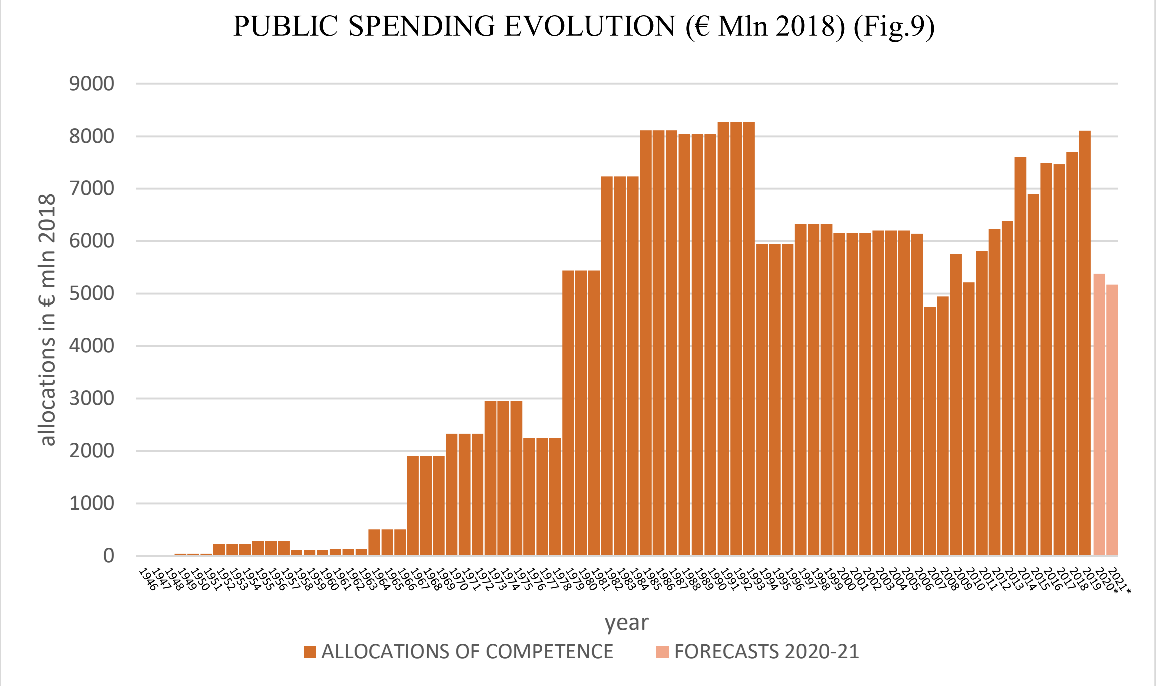
In order to harmonize data from the different sources analyzed and provide a final big picture, total estimated yearly expenditures are reassessed based on ISTAT price indexes at 2018. Moreover, the two estimated series, (the one based on ANCE and CRESME Report from 1944 to 2009 and the other on official Budget Documents covering from 2007 onward), overlapped indeed for three years. What we can see (*Tab.2*), is that despite different sources, total estimated expenditures (in real terms) don't seem to differ substantially:

OVERLAPPING YEARS IN THE TWO SERIES (2018 € billion) (Tab.2)

| | **1944-2009 series** | **2007-2019 series** |
|---|---|---|
| 2007 | 5.1 | **4.75** |
| 2008 | 4.95 | **4.95** |
| 2009 | 4.7 | **5.75** |

The last figure is significantly higher for data from Budget Documents, as the tail of the first series (1944-2009) is a projection of average allocations earmarked in previous years, not accounting for Abruzzo *(*2009*)* earthquake. In the two previous years errors are instead narrower. For these three years, figures from official Budget Documents will be kept due to greater precision.

For a matter of graphical representation, sums from 1946 (first allocation) to 2005, are represented as an average of subsequent three-year periods (*Fig.9*).



Overall total public allocations amount at around €307.85 billion (2018 prices). Forecasts for 2020 and 2021 show much lower figures with respect to previous years (€10.55 billion overall). Total resources devoted to natural hazards and disasters appear to be very low in the first twenty years of the series, accounting for just €3.9 billion until 1966. Thereafter, allocations start growing, experiencing a steep rise from the mid-seventies to the nineties. After flattening and decreasing during the nineties and the early 2000s, earmarked public funds start rising gradually from 2007 up to present days.

Some considerations can be made comparing the series of total appropriations (*Fig.9*) to the ones of the frequency of natural disasters presented in the previous chapter (*Fig.6; Fig.7*): while the number of natural disasters, despite its intrinsic yearly variability, showed an average increase during the last seventy-five years, the dynamics of public allocations seem to follow a different pattern. In fact, the maximum level of yearly appropriations was reached between the mid-eighties and early-nineties, when figures attested on average above the equivalent of €8 billion each year, a level never reached thereafter until 2019 when, according to the last Budget Law, a total of approximately €8.11 billion was allocated after a continual growth during the last twelve years.

On the whole, a major determinant in the evolution of the economic impact on public finances seem to be attributable, more than to the yearly number of disasters, to the magnitude of those more catastrophic, namely earthquakes. Surely, a non-negligible role is also played by investments for hydrological hazards, that were absent just after the WW II, but started growing during the sixties continuing up to present days. However, figures are more regular and restrained (plus, back to *§1.5*, hydrological disasters spike in a period when overall costs fall). The economic impact of climate-meteorological events, as of relative allocations, is instead almost null.

A deeper look into data, sheds light on the fact that the first rise in the late-sixties is mainly due to Belice earthquake (1968), which accounted alone for the equivalent of almost €9.4 billion, followed within twelve years by two other major earthquakes in Friuli (1976, overall impact of almost €21 billion) and Irpinia (1980, €65 billion). The accumulation of appropriations for these three events is the first responsible for the steep rise between the seventies and the early-nineties. Just one major earthquake hit Italy in the late-nineties (Marche, 1997) allowing for public finances to dispose of allocations from the previous ones. From 2009 onward, three earthquakes occurred in seven years: *Abruzzo (2009), Emilia (2012), Central Italy (2016)* impacting significantly on expenditures over the last decade (approximately €40 billion). All together, these seven events, which represent just 4.7% of total natural disasters, accounted for 50% of the overall economic impact.

Nowadays, earthquakes, which represent 25% of total natural disasters (*§1.5*) constitute by far the major disaster risk in Italy in terms of overall economic damages (but also of life losses, *§1.5*), accounting for more than the appropriations for all other events together. Based on 2012 classification from the Civil Defense Department, 38.5% of Italian municipalities are exposed to high seismic risk (ANCE and CRESME 2012), accounting for 44% of the National surface. Moreover, if an anti-seismic legislation for new constructions was introduced in 1974, 60% of total buildings in Italy were constructed before 1971 and another 16% between 1972 and 1981, thus not following the technical guidelines laid down by law. In addition to this, buildings constructed after 1974 might not comply anyway with current anti-seismic legislation, as the seismicity-risk map was updated several times in recent years. Yet, organic investments for seismic risk prevention were introduced only in 2009, when a €963 million fund was instituted, to be distributed in seven years on a regional basis. Estimates from the *Italian Association of Engineers and Architects*, show that approximately €36 billion would be needed to secure building in high-risk areas (Tripodi 2013). Much more than the sums allocated by now, but still less than 20% of total public expenditures for earthquakes in the last seventy-five years.

## 2.3 FOCUS ON RECENT MAJOR EARTHQUAKES

Three major earthquakes affected Italy during the last ten years: *Abruzzo (2009)*, *Emilia (2012)* and *Central Italy (2016)*. In Abruzzo, a 5.9 magnitude earthquake shook the region in April, majorly affecting L'Aquila province, with some municipalities in Pescara and Teramo also damaged. The seismic event was constituted by one major quake, followed by secondary ones in the immediately following days.

The earthquake occurred in Emilia was instead constituted by two major quakes on the 20th and 29th of May. The former with a magnitude of 6.1 (Richter), the latter of 5.9, both with epicenter in Modena province (but the swarm counted five more quakes with an intensity over the 5th grade). Other involved provinces were Ferrara, Bologna, and Reggio Emilia.

The last event, occurred in Central Italy, presented some peculiarities with respect to the previous ones in terms of temporal and spatial extension. For first, the three main quakes were not one close to another, but occurred on August 24th, October 26th- 30th, and January 18th of the following year. While the first epicenter (6.0 magnitude) was located in Lazio (Rieti province), the second and the third ones were centered in Marche (Macerata) and Umbria (Perugia) regions (respective magnitude: 5.9 and 6.5). The epicenter of the last quake was in Abruzzo (L'Aquila province), magnitude 5.5. Most profoundly damaged towns were in Rieti and Perugia provinces but, in terms of width, Macerata province saw 44 over 55 affected municipalities. Totally, the event involved nine provinces (Ancona, Ascoli Piceno, L'Aquila, Fermo, Macerata, Perugia, Rieti, Teramo and Terni), over four regions (Marche, Lazio, Umbria, Abruzzo).

Considering the temporal proximity, no long-term consideration would be possible yet, but a brief overview on the nature of appropriations occurred during the immediately following years, can be conducted. Such a sequence of disasters within just a few years, put considerable pressure on public finances: total appropriations are estimated to be around €40.6 billion overall (UVI 2018): 17.5 billion for the first earthquake, 8.4 for the second, 14.7 for the last one (within the following year were allocated, respectively: €2.3, 2.225 and 3.1 billion). A detailed insight on appropriations is provided by publications from the Italian Senate (UVI 2017; UVI 2018). Allocated funds can be divided in four categories: emergency funds, funds directed to support economic activities, transfers to local authorities and reconstruction funds. While the first three funding categories tend to be entirely allocated in the immediate aftermath of disasters, reconstruction resources are distributed over longer periods of time, showing heterogeneous patterns.

Focusing on the year of the event and the year after it, what we can see is that in *Abruzzo* 7.75% of total reconstruction funds were allocated the same year of the disaster, 15.7% within the following year, constituting 44% of total resources appropriated within that period. In *Emilia*, immediate reconstruction funds accounted for 11.6%, while the year after almost 27% were already allocated. In this case, during the first two years, the weight of resources devoted to reconstruction, represented indeed 81.2% of total allocations. Considering the last earthquake (2016) instead, reconstruction resources were allocated just for a 0.3% immediately, and 9.24% within the following year. Although it has to be considered that this event occurred in the second half of the year, contrarily to the previous ones, more resources were in this case devolved to support economic activities and financial needs of the population, accounting for some €1.36 billion the year of the disasters, versus almost null (€33 million) reconstruction allocations (UVI 2018).

The next chapter will look deeper, through some empirical estimates, into the *economics* (the impact on local economies) of these three disasters.

# CHAPTER 3: ESTIMATES OF SHORT-RUN ECONOMIC IMPACT OF EARTQUAKES: The cases of *ABRUZZO (2009), EMILIA (2012), CENTRAL ITALY (2016)*

## 3.1 THE CONTEXT

When an earthquake occurs, immediate (indirect) output losses follow, due to capital stock destruction (direct loss). Output losses might be compensated or not by the reconstruction process, depending on the *flexibility* of local economic systems (*§1.2*). Looking at Italy (*Ch.2*), reconstruction is entirely funded by different kinds of public transfers. Focusing on the post-crisis 2008 scenario, it seems reasonable to expect a certain degree of *flexibility* from the Italian (re)construction sector, and therefore any fall in output to be mitigated, at least in the short-run, by reconstruction incentives. The net impact on output changes, depends on the extent to which immediate negative effects of earthquakes are offset, or more than offset, by rebuilding works. A primary role is also played by the timing and size of government spending following the disaster, with its multiplicative effects on consumption and investments (Codogno 2016). In addition to this, the pre-quake institutional quality matters as well, as the reconstruction process might in turn stimulate corruption, thus reducing the offsetting effects (Barone and Moccetti 2014).

The aim of this chapter is to estimate empirically how local economies reacted short-term, after the last three major earthquakes occurred in Italy*: Abruzzo (2009), Emilia (2012)* and *Central Italy (2016)* (*§2.3*).

To investigate these events, a *difference-in-difference* approach will be employed, due to the *quasi-experimental* setting provided by earthquakes shocks. With reference to estimates of the economic impact of earthquakes in Italy, Porcelli and Trezzi (2014) adopted an analogue methodology, finding no significant change in provincial output in correspondence of seismic events, over the period 1986–2011. The same theoretical approach will be followed; however, each event will be considered separately, with a more disaggregated (municipal-level) focus, leading to partially different results. The next section will introduce the methodology, the following two will illustrate data and estimates results.

## 3.2 QUASI-EXPERIMENTS: *the diff-in-diff*

(Angrist and Pischke 2009; Stock and Watson 2007)

In Ideal Randomized Controlled Trials setting (*ideal experiments*), individual's *treatment effect* is defined as the difference in outcome of a certain variable of interest ($Y_i$), between a situation in which an individual receives a treatment ($X_i = 1$), and a situation in which the individual is not treated ($X_i = 0$). For a given subject, however, it is not possible to observe outcome under both situations: for each individual there exist two *potential outcomes* $\left(Y_i(0)\ and\ Y_i(1)\right)$, but only one is actually observable. Therefore, the treatment effect on a single individual is not measurable. However, it is possible to estimate the *average treatment effect* in a certain population: if individuals are randomly sampled from the population of interest, and randomly assigned to a *treatment* and a *control* group, then

- the expected value of the treatment effect in the sample is the same as the average treatment effect in the population;
- the treatment ($X_i$) is independently distributed from all individuals' personal attributes, including their two potential outcomes $\left(Y_i(0)\ and\ Y_i(1)\right)$.

It follows that

$$\begin{aligned} &E\left[Y_i(1)\,|\,X_i = 1\right] - E\left[Y_i(0)\,|\,X_i = 0\right] \\ &= E[Y_i(1)] - E[Y_i(0)] \\ &= E[\,Y_i(1) - Y_i(0)] \\ &= Average\ treatment\ effect. \end{aligned}$$

To translate in regression framework, let

$$\begin{aligned} Y_i &= Y_i(1)\,X_i + Y_i(0)(1 - X_i) \\ &= Y_i(0) + [Y_i(1) - Y_i(0)]X_i \\ &= E[Y_i(0)] + [Y_i(1) - Y_i(0)]X_i + (\,Y_i(0) - E[Y_i(0)]), \end{aligned}$$

and

$$Y_i(1) - Y_i(0) = \beta_{1i} \rightarrow\ treatment\ effect, assumed\ constant\ and\ equal\ to\ \beta_1$$

$$E[Y_i(0)] = \beta_0\ \rightarrow expected\ outcome\ in\ the\ control\ group$$

$$Y_i(0) - E[Y_i(0)] = u_i\ \ \rightarrow error\ term.$$

Then

$$Y_i = \beta_0 + \beta_1 X_i + u_i,$$

since the treatment $X_i$ is randomly assigned, it will not be correlated to $u_i$, so

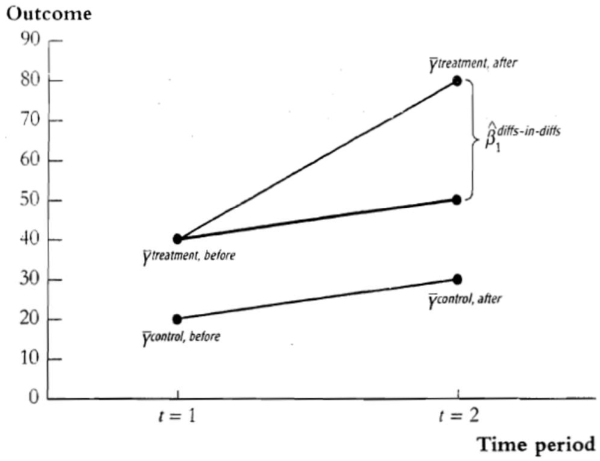
$$E(u_i \mid X_i) = 0,$$

and the OLS estimator of $\beta_1$, called here the *differences estimator*, will be unbiased for the average treatment effect of $X$ on $Y$.

Differently from experiments, in *quasi-experiments* (or natural experiments) treatment assignment is not the result of a conscious randomized trial, but arises from individual circumstances, for example from natural randomness (e.g. being hit by an earthquake or not) such that the treatment appears to be *as if randomly assigned.* As there is no control over the randomization process, some systematic differences might remain between treatment and control groups.

In order to adjust for these differences, one strategy is to compare changes in outcomes (from pre to post-treatment, $\Delta Y_i$), instead of outcome levels ($Y_i$), between the two groups. This leads to the *difference-in-difference* estimator, accounting for differences across groups (*treatment vs control*) and over time (*pre-treatment vs post-treatment*) (*Fig.10*). On one hand, looking at post-treatment differences only, we would impute initial differences in the two groups as treatment effect; on the other, accounting just for changes over time within the treatment group, we would consider all the factors that make outcome change as an effect of the treatment.

THE *DIFF-IN-DIFF* (Fig.10)



(source: STOCK, J. H., & WATSON, M. W. (2007). *Introduction to econometrics*. Boston, Pearson/Addison Wesley)

What we consider is, therefore, the difference between change in outcome in the treatment group and change in outcome in the control group, using the latter to approximate change the treatment group would have undergone, under no-treatment scenario.

This approximation relies on a *parallel trend assumption,* meaning that we assume the two groups would have had the same trend if the treatment were not implemented (e.g. the earthquake did not happen), which is a credible assumption if the treatment is as if randomly assigned:

$$\Delta Y^C(0) \simeq \Delta Y^T(0).$$

This framework translates in regression notation as

$$\Delta Y_i = \beta_0 + \beta_1 X_i + \gamma' W_i + u_i,$$

where $\Delta Y_i$ is the pre-post-treatment difference, $\beta_0$ is the expected change in outcome under no treatment, $X_i$ is a dummy variable on the treatment and $\beta_1$ is the treatment effect. A set $W_i$ of additional controls can be included: these variables must measure individual characteristics antecedent to the implementation of the treatment and, therefore, not affected by it. Controls can be added to improve estimates precision and/or to ensure that the treatment is as if randomly assigned, conditional on $W_i$. That is, the conditional mean independence condition must be satisfied

$$E(u_i \mid X_i, W_i) = E(u_i \mid W_i)$$

and the OLS estimator of $\beta_1$, called here the *difference-in-difference* estimator, will be unbiased for the expected differential change in outcome between treatment and control group.

## 3.3 METHODOLOGY AND DATA

In order to describe the change in output in the three earthquakes of *Abruzzo, Emilia,* and *Central Italy*, seven *diff-in-diff* models are drawn up.

Porcelli and Trezzi (2014) is the starting point.

They estimated

$$Y_{p,t} = \alpha_p + \gamma_t + \beta * earthquake_{p,t} + \theta' X_{p,t} + \varepsilon_{p,t},$$

where

$$Y_{p,t} = \frac{Y_{p,t} - Y_{p,t-1}}{Y_{p,t-1}}$$

is the percentage change in provincial ($p$) output (GDP) between the year before and the year of the earthquake. The model is estimated on 22 earthquakes occurred in Italy between 1986 and 2011. In the main specifications, the treatment group (*earthquake)* is constituted either by affected provinces or only by the province where the epicenter was, whereas the control group is made up of similar provinces for economic dynamics.

The theoretical regression design used here is similar to this, but some differences apply in terms of contents and specification.
For first, in this work, the three events are not considered all at once, but individual models are specified. Moreover, focus is at a municipal instead of provincial level: the treatment group is constituted by all affected municipalities, while the control group includes all non-affected municipalities in the same provinces of those affected. A provincial fixed effect factor is included in models for *Abruzzo* and *Emilia's* earthquakes, where disasters affect different provinces from the same region; a regional one instead for the one in *Central Italy*, as it involves multiple provinces within different regions. Provincial/regional effects are also interacted with the treatment, to differentiate for potentially diverse effects over different locations. When relevantly present (only in the case of the earthquake in *Emilia*) the treatment is also interacted with industrial districts presence, to see whether the differential change in output could be different depending on the presence of agglomerations of specialized firms.

One major issue is to collect yearly-updated data at a municipality level. Although yearly municipal GDP is not available, the Italian Department of Finance publicly releases some municipal data on tax records, namely the total tax base on which IRPEF tax is computed (Dipartimento delle Finanze 2019). IRPEF is a direct, personal and progressive tax payable by every physical person resident in the Italian territory, or non-resident but producing revenues in Italy (Dipartimento delle Finanze 2017). Taxed revenues are those of employees, autonomous workers, property capitals and business incomes. It is also due by companies of people ("Società di Persone"), and by limited companies in case they opt adopt the so-called *transparency taxation.* The change in the total municipal IRPEF tax base is assumed to be a good proxy for the change in output over the same period and will therefore be taken as dependent variable in the models.

A set of controls is put together assembling data from different sources. Available controls are:

- Number of residents and percentage of foreigners (ISTAT s.d. -a);
- Number of taxpayers by income bracket (Dipartimento delle Finanze 2019);
- Number of economic activities by macro-sector (Infocamere s.d.);
- Number of tourists (for *Abruzzo* earthquake), number of beds in accommodation establishments (ISTAT s.d. -b);
- Number of bank counters (Banca d'Italia 2008; 2011);
- Industrial districts (ISTAT 2011);
- Number of individual companies and companies of people (*Abruzzo* earthquake, ISTAT 2001).

For earthquakes occurred in *Abruzzo* and *Emilia,* two models each are specified. The first estimates the differential percentage change in output from the year before to the year of the disaster $\left(\Delta\%Y_i = \frac{Y_{i,t}-Y_{i,t-1}}{Y_{i,t-1}}\right)$, between affected and non-affected municipalities; the second repeats the same exercise, considering however the differential from the year before the disaster to the year after it $\left(\Delta\%Y_i = \frac{Y_{i,t+1}-Y_{i,t-1}}{Y_{i,t-1}}\right)$. *For Central Italy*, one supplementary model is added, considering as dependent variable the differential from *t* to *t+1* $\left(\Delta\%Y_i = \frac{Y_{i,t+1}-Y_{i,t}}{Y_{i,t}}\right)$.

The general regression notation of difference-in-difference models (*§3.2)*, applies here as follows:

*Abruzzo (2009)*

$$\Delta\%Y_i = \beta_0 + \beta_1 Earthquake + \beta_2 Province + \beta_3\,(Earthquake * Province) + \gamma' W_i + u_i$$

*Emilia (2012)*

$$\Delta\%Y_i = \beta_0 + \beta_1 Earthquake + \beta_2 Province + \beta_3\,(Industrial\ District) + \\ + \beta_4\,(Earthquake * Province) + \beta_5\,(Earthquake * Industrial\ District) + \gamma' W_i + u_i$$

*Central Italy (2016)*

$$\Delta\%Y_i = \beta_0 + \beta_1 Earthquake + \beta_2 Region + \beta_3\,(Earthquake * Region) + \gamma' W_i + u_i$$

The interpretation of the second model (the first and the third are just simpler specifications of this) is the following:

$\Delta\%Y_i$ = percentage change in output (over one or two years) in each municipality ($i$);

$\beta_0$ = percentage change in non-affected municipalities ($Earthquake = 0$) of the baseline province;

$\beta_1$ = differential percentage change between affected ($Earthquake = 1$) and non-affected municipalities of the baseline province;

$\beta_2$ = differential in the percentage change among non-affected municipalities in the baseline province and non-affected municipalities in provinces specified by the levels of $Province$;

$\beta_3$ = additive effect to the percentage change in output arising from the municipality to be in an Industrial district ($Industrial\ District = 1$);

$\beta_4$ = differential in the percentage change among affected municipalities in the baseline province and affected municipalities in provinces specified by the levels of $Province$;

$\beta_5$ = differential in the percentage change between affected and non-affected municipalities which are part of an industrial district;

$W_i s$ = set of controls specific for each model.

## 3.4 RESULTS

The three following tables summarize the most relevant results from the models set up for the three natural disasters. Tables only include covariates of interest, while each set of controls is omitted from these outputs, to help an immediate comprehension. Complete regression results (including controls) are reported in the Appendix. All regressions here report heteroskedasticity-robust standard errors.

Although each event presents its own peculiarities, in the majority of cases a significant *positive* differential in output change could be traced between affected and non-affected municipalities. Moreover, provinces of epicenter always experienced larger output spreads than all the others. However, if this emerges clearly and unquestionably in *Abruzzo* and *Emilia*, conclusions are less clear in *Central Italy* where, over the two years, some estimated differentials are negative.

**Abruzzo(2009) (Tab.3)**

| | 1-year % change<br>(1) | 2-year % change<br>(2) |
|---|---|---|
| Constant(L'Aquila) | 0.013 | 0.020 |
| | (0.013) | (0.016) |
| earthquake(L'Aquila) | $0.080^{***}$ | $0.118^{***}$ |
| | (0.013) | (0.017) |
| Pescara | $-0.017^{**}$ | $-0.024^{**}$ |
| | (0.008) | (0.012) |
| Teramo | $-0.024^{***}$ | $-0.033^{***}$ |
| | (0.007) | (0.011) |
| earthquake*Pescara | $-0.062^{***}$ | $-0.084^{***}$ |
| | (0.020) | (0.024) |
| earthquake*Teramo | $-0.041^{*}$ | $-0.053^{*}$ |
| | (0.021) | (0.028) |
| *N* | 201 | 201 |
| $R^2$ | 0.501 | 0.539 |
| Adjusted $R^2$ | 0.442 | 0.484 |
| F Statistic (df = 21; 179) | $8.553^{***}$ | $9.947^{***}$ |

*Notes:* $^{***}$Significant at the 1 percent level.
$^{**}$Significant at the 5 percent level.
$^{*}$Significant at the 10 percent level.

**Emilia(2012) (Tab.4)**

| | 1-year % change<br>(1) | 2-year % change<br>(2) |
|---|---|---|
| Constant(Bologna) | -0.006 | 0.004 |
| | (0.005) | (0.008) |
| earthquake(Bologna) | $0.039^{***}$ | $0.044^{***}$ |
| | (0.005) | (0.005) |
| Ferrara | 0.007 | $0.015^{**}$ |
| | (0.005) | (0.007) |
| Modena | $0.018^{***}$ | $0.032^{***}$ |
| | (0.004) | (0.007) |
| Reggio Emilia | $0.009^{*}$ | $0.015^{**}$ |
| | (0.005) | (0.006) |
| Industrial District | 0.003 | 0.001 |
| | (0.004) | (0.006) |
| earthquake*Ferrara | $-0.016^{*}$ | -0.016 |
| | (0.009) | (0.011) |
| earthquake*Modena | $0.043^{***}$ | $0.045^{***}$ |
| | (0.010) | (0.012) |
| Earthquake*Reggio Emilia | -0.015 | $-0.024^{*}$ |
| | (0.011) | (0.014) |
| Earthquake*Industrial district | $0.030^{***}$ | $0.039^{***}$ |
| | (0.010) | (0.013) |
| *N* | 170 | 170 |
| $R^2$ | 0.847 | 0.811 |
| Adjusted $R^2$ | 0.824 | 0.783 |
| F Statistic (df = 22; 147) | $36.909^{***}$ | $28.724^{***}$ |

**Central Italy(2019) (Tab.5)**

| | 1-year % change (t-1 to t) (1) | 1-year % change (t to t+1) (2) | 2-year % change (3) |
|---|---|---|---|
| Constant(Abruzzo) | 0.002 | -0.005 | -0.003 |
| | (0.007) | (0.007) | (0.010) |
| earthquake(Abruzzo) | -0.009 | -0.011 | $-0.020^{**}$ |
| | (0.007) | (0.007) | (0.010) |
| Lazio | $-0.044^{*}$ | $0.064^{**}$ | 0.011 |
| | (0.025) | (0.025) | (0.020) |
| Marche | $0.016^{*}$ | -0.002 | 0.014 |
| | (0.009) | (0.009) | (0.013) |
| Umbria | $0.021^{*}$ | 0.002 | $0.022^{*}$ |
| | (0.011) | (0.011) | (0.012) |
| Lazio*earthquake | 0.012 | 0.019 | $0.034^{**}$ |
| | (0.017) | (0.017) | (0.016) |
| Marche*earthquake | $-0.025^{***}$ | $0.022^{***}$ | -0.004 |
| | (0.008) | (0.008) | (0.011) |
| Umbria*earthquake | 0.011 | -0.00001 | 0.010 |
| | (0.013) | (0.013) | (0.012) |
| *N* | 495 | 495 | 495 |
| $R^2$ | 0.137 | 0.132 | 0.091 |
| Adjusted $R^2$ | 0.108 | 0.103 | 0.060 |
| F Statistic (df = 16; 478) | $4.732^{***}$ | $4.552^{***}$ | $2.978^{***}$ |

*Abruzzo (2009) (Tab.3)*

In all the provinces involved, output growth was significantly higher in affected municipalities than in non-affected ones. In the majorly involved province (L'Aquila), estimated output differential attested at 8% the year of the event, 11.8% one year after. Still significantly positive, but narrower differentials emerged in the two other involved provinces: Pescara (1.8% at *t* and 3.4% at *t+1*) and Teramo (3.9% and 6.5%).

*Emilia (2012) (Tab.4)*

Some relevant differences emerged among provinces. The most affected one, Modena (where the majority of involved municipalities is located) was where largest spreads were estimated: 11.2% the first year and 12.8% the second for *in-district* municipalities, 8.2% and 8.9% for the others. Bologna showed positive differentials as well: 3.9% and 4.4% (no industrial district is present), and estimates for Ferrara province were not highly significantly lower than these.

Similarly, in Reggio Emilia province, the estimated output spread is always positive, both *in-district* (between 6% and 7%) and *out-of-district* (between 2% and 3%).

### *Central Italy (2016) (Tab.5)*

Contrary to the two previous events, the picture is here much less defined. For this reason, the differential between *t* and t+*1* was also estimated (and not only *t-1 to t* and *t-1 to t+1*). In general, average output estimated differential changes do not seem to show constant tendencies between affected and not affected municipalities. In Abruzzo, Marche and Umbria estimated output differentials are moderately negative (around -2%) over the two-year timeframe, while some positive estimates result only in Lazio (where the epicenter of the first quake was, *§2.3*): here estimates for the differential change are 1.4%. Marche province follows particular (estimated) dynamics: the differential appears to be negative (-2.5%) the year of the event, but positive the following one (2.2%), with a net negative differential over the two years. It is however important to notice that the $R^2$s of models for this last event are much lower than for the previous ones.

Following the framework introduced in *§1.2,* not expecting although to accomplish an exhaustive scrutiny, it seems to emerge that post-disaster aids at least cushion the initial output fall due to the shock, with a different net effect depending on the considered event. In *Abruzzo* and *Emilia,* the constantly positive sign in the estimated taxable income differential might be attributed to an effective and prompt *reconstruction stimulus* (additional production necessary to restore the destructed part of the municipal capital stock). This, instead, does not appear in the last earthquake (at least in the considered years) except, feebly, in Lazio (where only Rieti province is considered). The negative estimates in 2016 earthquake (although not very large) might be justified by the different timing in funds allocation, together with the greater economic weakness due to the earthquake occurred just seven years before in Abruzzo. This interpretation would indeed be aligned with what emerged in *§2.3*: if for *Abruzzo* and *Emilia* earthquakes a relevant part of total necessary reconstruction funds were already allocated in the very first years (namely those under analysis), for the last earthquake the fraction of reconstruction allocations relative to the total necessary is much lower, in favor of larger initial instalments in emergency funds and in aids to companies that interrupted their activity.

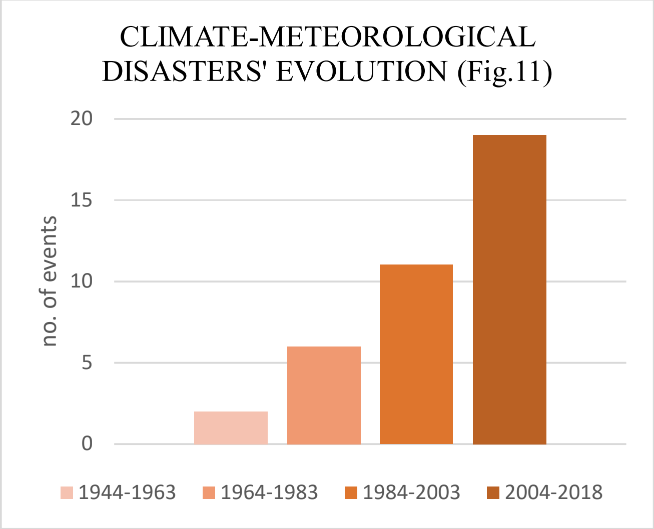
Following this stream, emergency funds would help curbing output losses short-term (negative differentials in Central Italy are indeed relatively limited), but only reconstruction funds would effectively contribute to restore capital stock losses, thus more than outweighing the initial fall.

Moreover, if the first two earthquakes occurred within a narrower spatial and temporal extension, the last one involved multiple quakes over a larger geographical extension and a longer period, partially at the turn of two years, potentially undermining estimates and the quasi-experimental design quality. In addition to this, there are unobservable populations' characteristics (e.g. *resilience*) that econometric models cannot capture. Doubts might also arise on whether changes in the tax base can be a reliable proxy for output changes. In fact, if the tax base grew also because of tax breaks and therefore of emergence of some tax evasion, then output differentials would be overestimated. Nevertheless, if there were *stimulus spillovers* to non-affected neighboring municipalities (this work implicitly assumes only residents in affected municipalities benefit from reconstruction aids), then the differential spread would be underestimated.

Although other dynamics might have concurred to these results, nevertheless the cues emerged throughout this analysis on the reciprocal relationships among public aid, reconstruction stimulus, taxation and local economic resilience might be a good starting point for further research on this topic.

## CHAPTER 4: FINAL CONSIDERATIONS ON NATURAL DISASTERS FUTURE TRAJECTORIES

If an *economic focus* has been posed on earthquakes more than on other disasters categories, this is because in the last seventy-five years these were by far the most impactful events. However, this does not mean that future dynamics will be the same. Although frequency and cost dynamics don't seem to share a common trend (*§2.2*), while the number of disastrous earthquakes fell over the last decades, the number of other events, namely climate-meteorological ones, have shown a sustained growth (*§1.5*) (*Fig.11*).



Moreover, analyses like the one conduced in previous chapters, as already pointed out, tend to *conceal under the radar* these disasters (*§1.5*) due to their more gradual evolution both in terms of frequency and in terms of post-event allocations (*§2.2*). In this state of affairs, climatological and meteorological events are better investigated through more specific analyses: studies on droughts, extreme hot or cold temperatures, violent storms and so on, provide more significant guidance when conduced on frequent observation, transcending the disastrous nature of events. Adopting this different focus, is possible to investigate for example how much of extreme temperatures growth can be attributed to anthropogenic forcing (Pasini et al. 2017), or the evolution of spatial and temporal extension of drought periods (ISPRA s.d.), or the constant rise of average sea levels (Lindsey 2018), and so on.

The evolution trajectories of these events, which turned into disasters in Italy "just" thirty-eight times over the last seventy-five years, are indeed hard task to forecast (Field et al. 2012), but for southern-Mediterranean region some tendencies can be outlined at a high confidence level:

projected changes show that the frequency and length of extreme heat waves is likely to increase, together with a significant rise in areas affected by droughts, while the frequency of cold nights and days is expected to decrease, and tropical storms are expected to increase (Field et al. 2012). Other disasters, not strictly natural, do not appear at all in this work, such as air pollution, which is estimated of having caused more than 60,000 deaths in Italy just in 2012 (European Environment Agency 2016).

These dynamics should not be overlooked: if extreme events arising from them appear as a minority in nowadays disasters databases records, relative weights might nevertheless change significantly in the future. Moreover, one most relevant difference applies: the occurrence of geophysical events cannot (of course) be affected, but their impact can be significantly mitigated through anti-seismic interventions realistically feasible in the medium-run (as for hydrological ones). Earthquakes with higher magnitudes than those registered in Italy occur worldwide, but generally result in more limited damages thanks to the widespread presence of anti-seismic constructions. On the contrary, regarding climatological and meteorological events, it would be myopic (and probably vain) to think in terms of mitigating their impact once they take place, instead of following global-level policies to reduce their anthropogenic occurrence. The economic impact of climate-related disasters, due to their non-reversible nature and their usually wide extension, could likewise be inestimably high, as to their relapse on local communities, economic activities, and overall regional growth paths.

In any case, it is unlikely to see expenditures for natural disasters decrease in the following years: although geophysical disasters diminished over the years, their economic impact did not, hydrological ones have been constant for the last two decades and climate-meteorological are incessantly rising. In this context, national policy makers should be mindful of the importance of mitigating now, through prevention interventions, the exposure to those disasters that are nowadays more frequent, as the weight of other kinds of events is likely to rise in the future, and so the financial needs to face them. Moreover, forward-looking international policies should be followed so as to curb the growth of "anthropogenic" natural disasters.

As learned from this work, natural disasters economics is still, to a large extent, an unexplored field, and it appears to be all the more complex, as economic estimates of shocks impact relate with multiple factors: business cycles phases, nature and timing of public aids, local economic structures, coping capacity and resilience of local communities, just to mention a few. Hence, the research focus is generally driven at a highly detailed level, so as to obtain reliable empirical estimates. It seems nevertheless important not to lose the big picture, to detect not only how disasters impact today, but also how they will evolve in the future, as this work tried to do.

## CONCLUSIONS

During the period 1944-2018, Italy was affected by 149 ascertained natural disasters, among which floods accounted for 35% and earthquakes for 25%. The latter were the most mournful, having caused more than seven-thousand deaths over the years. If, at a global level, natural disasters are unquestionably growing, at a national level the evolution appears instead to be more discontinuous and volatile. However, looking at decennial averages, values seem to be attesting at relevantly higher levels than seventy years ago. Some disasters categories, namely climatological and meteorological ones, showed a more sustained growth in the last decades.

All these events had an overall weight on public finances of estimated €308 billion (at 2018 prices) from 1946 onward. Figures have been dragged up by the strong incidence of a small share of events: 4.7% of these, all earthquakes, accounted for almost one half of total expenses. Despite this, allocations in anti-seismic prevention are relatively low (€963 million starting from 2009), while total estimated sums necessary to secure buildings in high-risk areas (44% of the Italian territory) attest at around €36 billion. This figure is anyhow lower than the estimated €40 billion allocated just for the last three major earthquakes in *Abruzzo (2009)*, *Emilia (2012*) and *Central Italy (2016*).

With respect to these three events, a municipality-level analysis on the impact of earthquakes, and subsequent aids, on local economies, was conducted. Exploiting the quasi-experimental setting provided by earthquakes, through a *difference-in-difference* approach, publicly available municipal tax records were used to estimate the differential change in output between affected and non-affected municipalities. Estimated differentials are always positive in *Abruzzo* and *Emilia,* arguably due to immediate *reconstruction stimulus,* more than outweighing initial output losses, attesting at most at +11.8% in *Abruzzo* and at +12.8% in *Emilia,* in epicenter provinces, one year after the disaster. For *Central Italy* earthquake, the only estimated positive differential one year after the event, appeared in Rieti province (Lazio, +1.4%), while output differentials are moderately negative in municipalities located in Abruzzo, Marche and Umbria (around -2%). Output decrease seems here to be only partially cushioned, presumably due to the different timing in reconstruction allocations and to the still weak economic fabric, already partially affected by the earthquake (*Abruzzo (2009)*) occurred seven years before.

From this simple analysis, further research could be conducted on the relationship between public aids nature and timing, taxation and local economies resilience. Reducing the economic exposure to present major disasters through prevention interventions, should be a primary concern for policy makers, as the incidence of climate-related events is constantly growing and might pose in the next decades, not only a significative additional pressure on public finances, but also relevant threats to the socio-economic equilibrium of vast areas of the National territory.

# APPENDIX

## I. DATASETS

All the datasets elaborated, for the reproducibility of results obtained, are available here for each chapter:

- *CHAPTER 1*: Natural disasters evolution
  https://drive.google.com/file/d/1y-XN5T2STc37SGM2QMeMaLOvBsG-B-42/view?usp=sharing
- *CHAPTER 2*: Public spending for natural disasters
  https://drive.google.com/file/d/1IqjWUqRCxBl8Gx6t_wAOZEp7IbFaxDwH/view?usp=sharing
- *CHAPTER 3*: Earthquakes in *Abruzzo(2009), Emilia(2012), Central Italy(2016*)
  https://drive.google.com/file/d/13KEa5nLCBb7TpVBYis2oNBP125JC0ATt/view?usp=sharing

## II. COMPLETE MODELS

(*legends are reported in the corresponding datasets*)

**Abruzzo(2009) (tab.3 complete)**

| | 1-year % change | 2-year % change |
|---|---|---|
| | (1) | (2) |
| Constant(L'Aquila) | 0.013 | 0.020 |
| | (0.013) | (0.016) |
| earthquake(L'Aquila) | $0.080^{***}$ | $0.118^{***}$ |
| | (0.013) | (0.017) |
| earthquake*Pescara | $-0.062^{***}$ | $-0.084^{***}$ |
| | (0.020) | (0.024) |
| earthquake*Teramo | $-0.041^{*}$ | $-0.053^{*}$ |
| | (0.021) | (0.028) |
| Pescara | $-0.017^{**}$ | $-0.024^{**}$ |
| | (0.008) | (0.012) |
| Teramo | $-0.024^{***}$ | $-0.033^{***}$ |
| | (0.007) | (0.011) |
| FR10000to26000 | $-0.00003^{**}$ | $-0.0001^{***}$ |
| | (0.00001) | (0.00002) |
| FR26000to55000 | $-0.0001^{*}$ | -0.0001 |
| | (0.0001) | (0.0001) |
| FR55000 | $0.001^{***}$ | $0.002^{***}$ |
| | (0.0004) | (0.001) |
| A | -0.00001 | 0.00004 |
| | (0.00003) | (0.00005) |
| C1 | $0.001^{***}$ | $0.001^{***}$ |
| | (0.0002) | (0.0002) |
| F | $0.0004^{***}$ | $0.001^{***}$ |
| | (0.0001) | (0.0002) |
| K | $0.002^{**}$ | 0.002 |
| | (0.001) | (0.001) |
| I | 0.0003 | 0.001 |
| | (0.0004) | (0.0004) |
| SocPers | $-0.001^{**}$ | $-0.001^{***}$ |
| | (0.0003) | (0.0003) |
| ImpInd | -0.0001 | -0.0001 |
| | (0.0001) | (0.0001) |
| touristPC | -0.00004 | $-0.0002^{**}$ |
| | (0.0001) | (0.0001) |
| foreign08 | 0.147 | 0.225 |
| | (0.188) | (0.242) |
| FR26000to55000:foreign08 | $0.004^{***}$ | $0.005^{**}$ |
| | (0.001) | (0.002) |
| FR55000:foreign08 | $-0.031^{***}$ | $-0.039^{***}$ |
| | (0.009) | (0.014) |
| FR10000to26000:K | $-0.00000^{***}$ | $-0.00000^{**}$ |
| | (0.00000) | (0.00000) |
| FR10000to26000:I:touristPC | $0.000^{***}$ | $0.000^{***}$ |
| | (0.000) | (0.000) |
| *N* | 201 | 201 |
| $R^2$ | 0.501 | 0.539 |
| Adjusted $R^2$ | 0.442 | 0.484 |
| Residual Std. Error (df = 179) | 0.046 | 0.060 |
| F Statistic (df = 21; 179) | $8.553^{***}$ | $9.947^{***}$ |

**Emilia(2012) (tab.4 complete)**

| | 1-year % change<br>(1) | 2-year % change<br>(2) |
|---|---|---|
| Constant(Bologna) | -0.006 | 0.004 |
| | (0.005) | (0.008) |
| earthquake(Bologna) | 0.039$^{***}$ | 0.044$^{***}$ |
| | (0.005) | (0.005) |
| earthquake*Ferrara | -0.016$^{*}$ | -0.016 |
| | (0.009) | (0.011) |
| earthquake*Modena | 0.043$^{***}$ | 0.045$^{***}$ |
| | (0.010) | (0.012) |
| Earthquake*Reggio Emilia | -0.015 | -0.024$^{*}$ |
| | (0.011) | (0.014) |
| Earthquake*Industrial district | 0.030$^{***}$ | 0.039$^{***}$ |
| | (0.010) | (0.013) |
| Ferrara | 0.007 | 0.015$^{**}$ |
| | (0.005) | (0.007) |
| Modena | 0.018$^{***}$ | 0.032$^{***}$ |
| | (0.004) | (0.007) |
| Reggio Emilia | 0.009$^{*}$ | 0.015$^{**}$ |
| | (0.005) | (0.006) |
| Industrial District | 0.003 | 0.001 |
| | (0.004) | (0.006) |
| foreignrate | 0.078 | 0.081 |
| | (0.056) | (0.083) |
| C1 | 0.0002$^{***}$ | 0.0003$^{***}$ |
| | (0.00003) | (0.00004) |
| F1 | -0.0001$^{***}$ | -0.0001$^{***}$ |
| | (0.00001) | (0.00002) |
| H | -0.0003$^{***}$ | -0.0005$^{***}$ |
| | (0.0001) | (0.0001) |
| K | 0.0001 | 0.00005 |
| | (0.0002) | (0.0003) |
| N | 0.0001 | 0.0002 |
| | (0.0002) | (0.0003) |
| bedsPC | 0.054$^{***}$ | 0.043$^{**}$ |
| | (0.014) | (0.020) |
| ProvFE:C1 | -0.00002 | -0.00004 |
| | (0.00002) | (0.00002) |
| ProvMO:C1 | -0.0001$^{***}$ | -0.0001$^{***}$ |
| | (0.00002) | (0.00002) |
| ProvRE:C1 | -0.00002 | -0.00004 |
| | (0.00003) | (0.00003) |
| foreignrate:bedsPC | -1.056$^{***}$ | -1.066$^{***}$ |
| | (0.218) | (0.321) |
| DistInd:C1 | -0.0001$^{***}$ | -0.0002$^{***}$ |
| | (0.00003) | (0.00004) |
| DistInd:K | 0.001$^{***}$ | 0.001$^{***}$ |
| | (0.0002) | (0.0003) |
| *N* | 170 | 170 |
| R$^2$ | 0.847 | 0.811 |
| Adjusted R$^2$ | 0.824 | 0.783 |
| Residual Std. Error (df = 147) | 0.017 | 0.022 |
| F Statistic (df = 22; 147) | 36.909$^{***}$ | 28.724$^{***}$ |

**Central Italy(2019) (tab.5 complete)**

| | 1-year % change (t-1 to t) | 1-year % change (t to t+1) | 2-year % change |
|---|---|---|---|
| | (1) | (2) | (3) |
| Constant(Abruzzo) | 0.002 | -0.005 | -0.003 |
| | (0.007) | (0.007) | (0.010) |
| earthquake(Abruzzo) | -0.009 | -0.011 | -0.020$^{**}$ |
| | (0.007) | (0.007) | (0.010) |
| Lazio*earthquake | 0.012 | 0.019 | 0.034$^{**}$ |
| | (0.017) | (0.017) | (0.016) |
| Marche*earthquake | -0.025$^{***}$ | 0.022$^{***}$ | -0.004 |
| | (0.008) | (0.008) | (0.011) |
| Umbria*earthquake | 0.011 | -0.00001 | 0.010 |
| | (0.013) | (0.013) | (0.012) |
| Lazio | -0.044$^{*}$ | 0.064$^{**}$ | 0.011 |
| | (0.025) | (0.025) | (0.020) |
| Marche | 0.016$^{*}$ | -0.002 | 0.014 |
| | (0.009) | (0.009) | (0.013) |
| Umbria | 0.021$^{*}$ | 0.002 | 0.022$^{*}$ |
| | (0.011) | (0.011) | (0.012) |
| DistInd | 0.008$^{***}$ | 0.014$^{***}$ | 0.022$^{***}$ |
| | (0.003) | (0.003) | (0.004) |
| foreignrate | -0.030 | 0.087 | 0.063 |
| | (0.082) | (0.082) | (0.113) |
| banksPC | -0.002 | -0.008 | -0.010 |
| | (0.006) | (0.006) | (0.010) |
| RegLazio:foreignrate | 0.334 | -0.602$^{***}$ | -0.203 |
| | (0.220) | (0.220) | (0.210) |
| RegMarche:foreignrate | -0.050 | -0.008 | -0.067 |
| | (0.100) | (0.100) | (0.135) |
| RegUmbria:foreignrate | -0.019 | -0.162 | -0.184 |
| | (0.104) | (0.104) | (0.132) |
| RegLazio:banksPC | 0.0004 | -0.013 | -0.008 |
| | (0.015) | (0.015) | (0.016) |
| RegMarche:banksPC | -0.005 | 0.001 | -0.003 |
| | (0.008) | (0.008) | (0.012) |
| RegUmbria:banksPC | -0.019$^{*}$ | 0.023$^{**}$ | 0.006 |
| | (0.010) | (0.010) | (0.012) |
| *N* | 495 | 495 | 495 |
| $R^2$ | 0.137 | 0.132 | 0.091 |
| Adjusted $R^2$ | 0.108 | 0.103 | 0.060 |
| Residual Std. Error (df = 478) | 0.036 | 0.034 | 0.044 |
| F Statistic (df = 16; 478) | 4.732$^{***}$ | 4.552$^{***}$ | 2.978$^{***}$ |

## III. R CODE

### a. Chapter 3

```
                            ###ABRUZZO(2009)###

abr1<- read.table("C:\\Users\\lazzarettop\\Desktop\\terremoto abruzzo\\aqn
ew.1.txt", header=TRUE, dec=",")
attach(abr1)
d<- abr1
names(d)
C1<- C


#These are the two codes of the models, used for models in Chapter 3 and
for complete outputs in the Appendix II (only different commands for the
output will be reported in the next section)


m1.1<- lm(dt1 ~ earthquake  + Prov + earthquake:Prov + FR10000to26000 + FR
26000to55000 + FR55000  + A + C1 + F + K + I + SocPers + ImpInd + FR26000t
o55000:foreign08 + FR55000:foreign08 + FR10000to26000:K + FR10000to26000:I
:touristPC + touristPC + foreign08)
summary(m1.1)


m2.2<- lm(dt2 ~ earthquake  + Prov + earthquake:Prov +  FR10000to26000 + F
R26000to55000 + FR55000 + A + C1 + F + K + I + SocPers + ImpInd + FR26000t
o55000:foreign08 + FR55000:foreign08 + FR10000to26000:K + FR10000to26000:I
:touristPC + touristPC + foreign08)
summary(m2.2)


library(sandwich)
cov1<- vcovHC(m1.1, type = "HC")
robust.se1<- sqrt(diag(cov1))
cov2<- vcovHC(m2.2, type = "HC")
robust.se2<- sqrt(diag(cov2))



library(stargazer)
stargazer( m1.1, m2.2, se=list( robust.se1, robust.se2), title = "Abruzzo(
2009) (Tab.3)", dep.var.labels = c("1-year % change", "2-year % change"),
intercept.top = TRUE, intercept.bottom = FALSE, type="text", omit=c("FR100
0to26000", "FR26000to55000", "FR55000", "A", "C1", "F", "K", "I", "SocPers
", "ImpInd", "touristPC", "foreign08"), out="tesi1.html", style="qje", omi
t.stat=c("ser"), covariate.labels = c("Constant(L'Aquila)", "earthquake(L'
Aquila)", "Pescara", "Teramo", "earthquake*Pescara", "earthquake*Teramo"),
notes.align = "l" )
```

```r
###EMILIA(2012)###

rm(list=ls())
d<- read.table("C:\\Users\\lazzarettop\\Desktop\\terremoto emilia\\em1305.txt", header=TRUE, dec=",")
attach(d)
names(d)

C1<- C
F1<- F

#These are the two codes of the models, used for models in Chapter 3 and for complete outputs in the Appendix II (only different commands for the output will be reported in the next section)



m1<- lm(dt1 ~ earthquake + Prov + earthquake:Prov + DistInd + foreignrate + C1 + F1 + H + K + N  + bedsPC + earthquake:DistInd + Prov:C1 + foreignrate:bedsPC + DistInd:C1 + DistInd:K)
summary(m1)


m2<- lm(dt2 ~ earthquake + Prov + earthquake:Prov + DistInd + foreignrate + C1 + F1 + H + K + N + bedsPC + earthquake:DistInd + Prov:C1 + foreignrate:bedsPC + DistInd:C1 + DistInd:K)
summary(m2)

library(sandwich)
cov1<- vcovHC(m1, type = "HC")
robust.se1<- sqrt(diag(cov1))
cov2<- vcovHC(m2, type = "HC")
robust.se2<- sqrt(diag(cov2))


library(stargazer)
stargazer( m1, m2, se=list(robust.se1, robust.se2), title = "Emilia(2012)(Tab.4)", dep.var.labels = c("1-year % change", "2-year % change"), intercept.top = TRUE, intercept.bottom = FALSE, type="text", omit=c("foreignrate", "C1", "F1", "H", "K", "N", "bedsPC"), out="tesi2.html", style="qje", omit.stat=c("ser"), covariate.labels = c("Constant(Bologna)", "earthquake(Bologna)", "Ferrara", "Modena", "Reggio Emilia", "Industrial District", "earthquake*Ferrara", "earthquake*Modena", "Earthquake*Reggio Emilia", "Earthquake*Industrial district"), notes.align="l")
```

```
                              ###CENTRAL ITALY(2016)###

d<- read.table("C:\\Users\\lazzarettop\\Desktop\\terremoto 2016\\1505.2.tx
t", header=TRUE, dec=",")
attach(d)
head(d)

#These are the three codes of the models, used for models in Chapter 3 and
for the complete outputs in Appendix II (only different commands for the
outputs will be reported in the next section)



m1<- lm(dt1 ~ earthquake + Reg + DistInd + foreignrate  + banksPC + Reg:fo
reignrate + earthquake:Reg + Reg:banksPC )
summary(m1)
m2<- lm(dt1617 ~ earthquake + Reg + DistInd + foreignrate  + banksPC + Reg
:foreignrate + earthquake:Reg + Reg:banksPC )
summary(m2)
m3<- lm(dt2 ~ earthquake + Reg + DistInd + foreignrate  + banksPC + Reg:fo
reignrate + earthquake:Reg + Reg:banksPC )
summary(m3)



library(sandwich)
cov1<- vcovHC(m1, type = "HC")
robust.se1<- sqrt(diag(cov1))
cov2<- vcovHC(m2, type = "HC")
robust.se2<- sqrt(diag(cov1))
cov3<- vcovHC(m3, type = "HC")
robust.se3<- sqrt(diag(cov3))

library(stargazer)
stargazer(m1,m2,m3, se=list(robust.se1, robust.se2, robust.se3), type="tex
t", intercept.top = TRUE, intercept.bottom = FALSE, out="2016robust.html",
title="Central Italy(2019) (Tab.5)", style="qje", omit=c("DistInd", "forei
gnrate", "banksPC"), omit.stat=c("ser"), dep.var.labels=c("1-year % change
(t-1 to t)", "1-year % change (t to t+1)", "2-year % change"), covariate.l
abels= c("Constant(Abruzzo)", "earthquake(Abruzzo)", "Lazio", "Marche", "U
mbria", "Lazio*earthquake", "Marche*earthquake", "Umbria*earthquake"), not
es.align = "l")
```

b. Appendix II

```
                        ###ABRUZZO (2009)###

library(stargazer)
stargazer( m1.1, m2.2, se= list(robust.se1, robust.se2), title = "Abruzzo(2009) (tab.3 complete)", dep.var.labels = c("1-year % change", "2-year % change"), order= c("Constant", "earthquake","Prov", "earthquake:Prov"), covariate.labels = c("Constant(L'Aquila)", "earthquake(L'Aquila)", "earthquake*Pescara", "earthquake*Teramo", "Pescara", "Teramo"),  intercept.top = TRUE, intercept.bottom = FALSE, type="text", out="appendix1.html", style="qje",no.space=TRUE, notes.align = "l")



                       ###EMILIA (2012)###

library(stargazer)
stargazer( m1, m2, se=list(robust.se1, robust.se2), title = "Emilia(2012) (tab.4 complete)", dep.var.labels = c("1-year % change", "2-year % change"), intercept.top = TRUE, intercept.bottom = FALSE, type="text", out="appendix2.html", style="qje", covariate.labels = c("Constant(Bologna)", "earthquake(Bologna)","earthquake*Ferrara", "earthquake*Modena", "Earthquake*Reggio Emilia", "Earthquake*Industrial district", "Ferrara", "Modena", "Reggio Emilia", "Industrial District" ), order=c("Constant", "earthquake"), notes.align="l")




                    ###CENTRAL ITALY(2016)###

library(stargazer)
stargazer(m1,m2,m3, se=list(robust.se1, robust.se2, robust.se3), type="text", intercept.top = TRUE, intercept.bottom = FALSE, out="appendix3t.html", title="Central Italy(2019) (tab.5 complete)", style="qje", dep.var.labels=c("1-year % change (t-1 to t)", "1-year % change (t to t+1)", "2-year % change"), covariate.labels= c("Constant(Abruzzo)", "earthquake(Abruzzo)", "Lazio*earthquake", "Marche*earthquake", "Umbria*earthquake", "Lazio", "Marche", "Umbria"),order=c("Constant", "earthquake"), notes.align = "l")
```

*Number of words from the Introduction (excluding codes text):* ***9937***

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