Earthquakes economic costs through rank-size laws

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Abstract

The presentation is devoted to explore the magnitude features of the earthquakes occurring in Italy between January 24th, 2016 and January 24th, 2017 in order to elaborate a proposal of cost indicator. The well known tragic seismic events with epicentres at Accumuli, Visso, Ussita, Castelsantangelo sul Nera, Norcia and Montereale have occurred during the aforementioned span of time. On this dataset, we develop two different rank-size analysis by using the standard Zipf-Mandelbrot Law (see Mandelbrot 1953, 1961) and the Universal Law proposed by Ausloos and Cerqueti [2016].
The idea of designing a measure to evaluate the economic impact of earthquakes is based on the obvious evidence of a cause-effect relationship between the magnitude of earthquakes and the economic cost deriving from them. We draw attention to the role of the infrastructures resistance into the relationship between the damages and the seismic events sequences, so we conjecture different forms of cost indicators.

Keywords: Earthquake, magnitude, economic cost, Zipf-Mandelbrot law, rank-size analysis, Italy.

Despite the fact that Italy comes from an eventful seismic history because of its geological conformation, the legislator has taken a series of myopic decisions during the years, leaving Italy dramatically exposed to damages generated by earthquakes. In fact, Italy has an old and poorly maintained

housing system that is very sensitive to seismic events, especially when they are in series and above a certain threshold.
The seismologists classify the entire planet by using different criteria based on the probability of an earthquake occurring into specific zones. Differently from the Italian case, Japan with its higher risk position of having a natural disaster, has gained a very good experience in anti-seismic buildings development. Indeed, thanks to a combination of innovation and law incentives, it has developed an effective strategy for reducing the damages and so the social cost.

In this proposal we take into consideration the Italian seismic events occurred between January 24^{th}, 2016 and January 24^{th}, 2017; we include the cases of August, 24^{th} 2016 in Accumuli and October, 26^{th} and 30^{th} 2016 in Ussita and Norcia beyond that minor shocks happened in Italy within the analysed span of time. The total number of temblors observed in the considered time frame of 365 days is 978, within a Richter magnitude range: [3.1 - 6.5]. The maximum level corresponds to the earthquakes of October 30^{th}, 2016 with the municipality of Norcia as epicentrum. While the minimum considered level 3.1 comes from different considerations. In the raw data downloaded from the Italian National Institute of Geophysics and Vulcanology (INGV), there is an enormous amount of minor shocks registered that are not able to generate damages. Indeed, according to the United State Geological Survey, the earthquakes with magnitude inferior to 3.1 have low chances of creating observable problems. Furthermore, adopting a cut-off at 3.1, the catalogue incompleteness problem is avoided. The so called catalogue incompleteness issue is met because the analyzed period is a very peculiar one with many relevant shocks occurred in a short span of time. It is so special that SISMIKO, the emergency seismic network at INGV, has installed an additional detection system to support the permanent one around the original epicentral area. It is required in order to lower the risk of not capturing the aftershocks that could remain out from the catalogue once a main shock is occurred. This kind of problem requires an additional effort from INGV which has to manipulate the raw data for completing the dataset (see Moretti et al. [2017]) ensuring a certain degree of uniformity in presenting the data. On the catalog completeness problems there are several studies recently developed. For example in Marchetti et al. [2016] the authors have determined a threshold of $M_c = 2.7$ for the revised catalog of shocks happened after the so called Amatrice earthquake (it is the shock occurred the August 24^{th}, 2016, known with the name of the town where the caused

damages were highest). They wrote that the lower bound that ensures the dataset completeness could rise to 3.1 and this is concordant with Chiaraluce et al. [2017].
In the time span under observation, the first major shock happened in August, 24^{th} 2016, and it could be considered as the kick off point after which the observations are affected by the aforementioned catalogue issue. So, before the Amatrice shock, the dataset should not be affected by incompleteness; therefore we can consider a $M_c = 2.5$ for the time series from January, 24^{th} 2016, to August, 24^{th} 2016 in accordance with Romashkova and Peresan [2013], Schorlemmer et al. [2010]. Anyway, the most prudential restriction at 3.1 is considered and it makes the dataset adequate for the cost analysis of the earthquakes.
The complete version of the catalog has very interesting properties from a rank-size point of view, especially when the Universal Law is employed; but it cannot be fruitfully used for evaluating economic cost as it will be shown.

We use two different rank-size laws to elaborate some functional relationships that allow providing indicators of the damages caused by different shocks. We implement many best fit procedures on the Zipf-Mandelbrot Law and on the Universal Law that is an extension of the Lavalette Law (Lavalette 1996) mainly differentiated by the number of parameters involved. In order to do so, we take up the Levenberg-Marquardt algorithm restricting the parameters within the positive field. This approach applied to the seismic data analysis is not new, many studies can be quoted as examples of investigation of the magnitudes by using rank-size approaches (see Aguilar-San Juan and Guzmán-Vargas [2013], Jaumé [2000], Mega et al. [2003], Newman [2005], Pinto et al. [2012], Saichev and Sornette [2006], Wu [2000]).

At the best of our knowledge, it is the first time that the recent Italian seismic events have been analyzed employing power laws, especially for damages quantification purposes. Specifically, the observed magnitudes along the considered period are transformed into costs by the means of the Zipf-Mandelbrot Law and the Universal Law calibrated on the mentioned catalogue. These cost indicators could be helpful in the definition of government policies with respect to the risk of natural disasters like the seismic events.

A robustness check of the outcomes has to be performed in order to draw reliable conclusions. For this reason we present additional analyzes on two different datasets. One is an enlarged catalog which contains the Italian seismic time series from the 16^{th} of April 2005 to the 31^{st} of March 2017, downloaded from the INGV website. In April 2005 has been established a new network for seismic events registration, it has been further improved by the time passing, but in order to avoid catalog incompleteness biases, for this dataset we consider a $M_c = 2.5$ as magnitude lower bound, as in Romashkova and Peresan [2013], Schorlemmer et al. [2010]. The second robustness check is based on a different data selection. Indeed, we explore the effect of the space on the considered variable by using a dataset covering January 24^{th}, 2016 - January 24^{th}, 2017. Starting from it, we make new sub-catalogs by picking seismic events with epicentres in the eight adjacent provinces affected the most during that period: Macerata, Perugia, Rieti, Ascoli Piceno, L'Aquila, Teramo, Terni and Fermo (with respective coasts).We perform the rank-size analysis on each of them. In this way, we are consistent with the scholars that point the irrelevance of spatial effects for short time periods and small regions as Natale et al. [1988]. Both the procedures addressed to validate the main analysis results give no signal of remarkable weaknesses. Indeed, in the first robustness check, we have obtained outcomes similar to those coming from the main analysis and, in the second test, the difference between provinces is not significant, therefore the main results can be considered valid.

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