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Earthquake hazard and civic capital☆

Paolo Buonanno[a], Giacomo Plevani[b], Marcello Puca[c,*]

[a] University of Bergamo, Via dei Caniana 2, 23127 Bergamo, Italy
[b] University of Torino, Italy
[c] University of Bergamo, CSEF, Webster University Geneva, Italy

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ABSTRACT

We examine the empirical relationship between the exposure to earthquake hazard and civic capital in Italian municipalities. Drawing on the Italian National Institute of Geophysics and Volcanology, we find that earthquake hazard increases civic capital. We exploit variation across neighboring municipalities and use a neighbor-pair fixed effect estimator to establish a causal link between earthquake hazard and the accumulation of civic capital. We decompose the effect of earthquake hazard variation along four dimensions – frequency, space, magnitude, and timing – and observe that the effect is mostly explained by high-magnitude seismic events in the past. Our results are in line with the intuition that cooperative social norms build over a very long time span.

1. Introduction

How do societies cope with negative shocks such as natural disasters? In a world where insurance markets are incomplete and the provision of public goods may not be perfect, individuals may adopt different strategies. One possible solution is turning to religion for psychological relief or mutual support (e.g. Van De Wetering, 1982; Ager and Ciccone, 2018; Sinding Bentzen, 2019). Another solution is strengthening the political power. In the past, viewing natural disasters as divine punishment reinforced the authority of political figures, who were also religious leaders (Belloc et al., 2016). More generally, efforts to deal with the adversities of life often imply solving social dilemmas, a problem that is germane to human co-existence (Enke, 2019).

This paper aims to shed light on such questions by investigating whether earthquakes induce humans to cooperate and, if this is the case, through which channels. More specifically, we study whether and in which direction earthquake hazard affects the set of good social norms often referred to as *civic capital* (Guiso et al., 2011). The answer is not straightforward. On the one hand, a disastrous event can spur chaos, looting and, more generally, individual opportunistic behavior (Winkler, 2021). On the other hand, the payoff from cooperation is higher after a disaster, giving individuals a greater incentive to behave pro-socially (Voors et al., 2012; Bai and Li, 2021).

A better understanding of this issue is crucial, as the role of civic capital in explaining cross-country differences in economic growth (Knack and Keefer, 1997; Zak and Knack, 2001), good governance (Knack, 2002), and, more generally, economic well-being (Guiso et al., 2011; Algan and Cahuc, 2014) is now well known. Yet, why (and how) some societies accumulate more civic

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* Corresponding author.
E-mail addresses: paolo.buonanno@unibg.it (P. Buonanno), giacomo.plevani@carloalberto.org (G. Plevani), marcello.puca@unibg.it (M. Puca).

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capital than others remains an open debate.[1] To the best of our knowledge, however, this paper is the first that explores whether the exposure to earthquake hazard is a contributing factor in the *long-run accumulation* of civic capital.

To this end, we employ geo-referenced information drawn from the historical dataset on earthquakes of the Italian National Institute of Geophysics and Volcanology, and construct several measures of earthquake hazard. This dataset is combined with proxies of civic capital for 8082 Italian municipalities. In line with previous literature, we focus on several dimensions of pro-social behavior conducive to the accumulation of civic capital (Putnam, 1993). Specifically, we consider: (i) the presence of an organ donation association, to assess the purely altruistic component of prosociality (Guiso et al., 2011); (ii) a measure of tax compliance as a proxy of individual willingness to free ride on contribution to a public good (Buonanno and Vanin, 2017); and (iii) the density of Catholic churches as a reflection of the religious-driven component of civic capital (Paldam and Paldam, 2017; Ager and Ciccone, 2018; Sinding Bentzen, 2019). As our measures of civic capital may be affected by other variables that are also correlated with earthquake hazard, we add a rich set of control variables to our estimates, including climatic, geographic, and historical information about each municipality. Using this wealth of information, we find that earthquake hazard increases municipality-level civic capital. Moreover, given that the effects of earthquakes are not contained within municipal administrative boundaries, we also allow the variation in earthquake hazard to have potential spatial spillovers from a given municipality to its neighboring municipalities. Our preliminary results remain stable after the inclusion of this possibility.

To establish a proper causal link between earthquake hazard and the accumulation of civic capital, we exploit variation across neighboring municipalities (Acemoglu et al., 2012). Our results, indeed, could be due to a mere correlation, given by the non-random location of earthquakes that are generated by movements of the terrestrial crust along well-known fault lines. One could therefore argue that societies close to these lines are systematically different from those living farther away. To address these concerns, we use a neighbor-pair fixed effect estimator, so that the effect of the earthquake hazard is identified by comparing municipalities that are similar in economic and geographical characteristics but for their exposure to earthquakes. Results confirm that earthquake hazard increases municipality-level civic capital. In particular, a rise of one standard deviation in the earthquake hazard augments civic capital, in our most conservative estimate, by at least 6.7% of a standard deviation. Moreover, we provide a series of additional estimates that address possible selection effects resulting from the comparison of municipalities that have never been hit by an earthquake to those located in very seismic areas. In particular, we run our estimations on a subsample of municipalities hit by an earthquake at least once. Our results are robust to the inclusion of other geographic characteristics, historical controls, the adoption of a restricted sample of powerful seismic events, different reference distances, and a series of falsification tests. We also check that our results are not driven by historical migrations and selection on information.

Our findings indicate a heterogeneous effect among hit municipalities, with those having more frequently experienced earthquakes displaying on average a higher level of civic capital. Moreover, the effect is primarily driven by high-magnitude events that occurred in the past. This finding is consistent with the inefficient provision of public goods in pre-unitarian Italian states, a situation that fostered returns to cooperation. Indeed, the burden of reconstruction fell mostly upon local communities (Guidoboni and Ferrari, 2000; Guidoboni, 2014). Our results also speak to the historical formation and long-term persistence of cultural norms as contributing factors in the accumulation of civic capital. To this regard, one might ask to what extent the reactive cooperative behavior to the inefficient provision of public goods in pre-unitarian states has persisted culturally in these communities. Guiso et al. (2016) show that historical shocks may, in fact, generate long-lasting differences in civic capital accumulation. This accumulation is the product of both within-household inter-generational value transmission (Cavalli-Sforza and Feldman, 1981; Bisin and Verdier, 2001; Dohmen et al., 2012) and the co-evolution of culture and institutions. Indubitably, there is a strategic complementary between norms of interpersonal cooperation and the institutions that enforce them (Tabellini, 2008). To be applicable in our case, both mechanisms therefore require persistent exposure to earthquakes so as to induce the accumulation of civic capital. This explanation is also consonant with the findings of Giuliano and Nunn (2020), who demonstrate that environmental similarity across generations is a key determinant of observed cultural trait persistence.

As seismicity is a very stable natural feature, we can reasonably assume that it is highly capable of having a persistent effect on societies' cultural traits. In adopting this view, we take a different approach relative to previous research, which has tended to focus on the short and medium term effects of (mostly) single seismic events. To this regard, scholars have explored saving and spending behavior (Filipski et al., 2019), social capital (Bai and Li, 2021; Giardini et al., 2022), crime (Hombrados, 2020), religiosity (Sinding Bentzen, 2019), GDP per capita (Barone and Mocetti, 2014), delayed transition to self-government (Belloc et al., 2016), public expenditures (Masiero and Santarossa, 2020), or electoral outcomes (Masiero and Santarossa, 2021).

Broadly, our results build on the literature investigating the role of disasters and negative shocks in shaping social norms and culture (Fong and Luttmer, 2009; Bauer et al., 2016). Our work also intersects with evolutionary anthropology research on social learning, which shows that norms and beliefs that maximize fitness to external constraints become prevalent in communities exposed to the same environment (Boyd and Richerson, 1988).

The remainder of the paper is structured as follows. Section 2 provides a conceptual framework that explains the relationship between earthquake hazard and civic capital. Section 3 describes the dataset used in our analysis. Section 4 introduces our baseline evidence. Section 5 provides causal evidence that earthquake hazard increases civic capital, while Section 6 presents robustness checks and additional evidence. Section 7 concludes.

[1] Some scholars believe that this accumulation has an institutional explanation (Putnam, 1993; Guiso et al., 2016), others point to differences in cultural norms (Kimbrough and Vostroknutov, 2016; Lowes et al., 2017), or intrinsic preferences (Bénabou and Tirole, 2006). Recent studies have investigated the role of natural resources (e.g. Buggle and Durante, 2021) or agricultural techniques (Alesina et al., 2013) in explaining heterogeneity in social norms.

2. Conceptual framework

The starting hypothesis of this paper is that the exposure to earthquakes spurred cooperative behavior among individuals, contributing to the accumulation of civic capital over time. To support this conjecture, we propose a series of mechanisms that explain this connection.

Extreme natural events have been a regular threat to human activities and lives throughout history (Buggle and Durante, 2021). Earthquakes, like other natural disasters, cause economic damage that reduces individuals' accumulated physical wealth and future productivity. However, not every earthquake has this effect. Some areas, for example, are affected by thousands of small or moderate seismic events per year that do not cause, most likely, economic damage. In this case, earthquake hazard is less likely to be a driver of cooperation. Disruptive or high magnitude earthquakes, conversely, which are concentrated along well known fault lines, destroy existing physical capital and slow down economic growth, thus giving to individuals the incentive to act cooperatively. For this reason, in our empirical exercise, we will mostly focus on high magnitude earthquakes. In the latter scenario, communities that are exposed to the hazard of high magnitude earthquakes find cooperation profitable, as it allows them to substitute physical capital with civic capital. Using a game theory approach, one could model this situation as a repeated Public Good Game, where members of the communities exposed to the hazard of future earthquakes must decide whether to contribute to the public good. Every community member makes this choice knowing that an idiosyncratic shock could reduce her payoff at future rounds. Therefore, the higher the earthquake hazard, the higher the probability that an individual contributes to the public good.[2] Given that individuals can, to some extent, anticipate *where* high magnitude earthquakes will occur but not *when*, we conjecture that communities living in areas that are more exposed to earthquake hazard are more likely to act cooperatively and contribute to the accumulation of civic capital, in anticipation of future adverse events.

If this mutual insurance mechanism works, implying that individuals can achieve better outcomes thanks to their cooperative behavior, one can reasonably believe that the positive externality generated by cooperation gets internalized in a community shared set of values (i.e., culture). Because individuals are uncertain about *when* an earthquake will hit the community, the social norms that bring about cooperation and the accumulation of civic capital are transmitted through time across different generations (Cavalli-Sforza and Feldman, 1981). This second mechanism, i.e. the cultural transmission, is consistent with our findings that show a positive effect on civic capital of "ancient" earthquakes, that is very old events that, once occurred, can shape the social values of a community almost indefinitely (see Section 5.2.4).

A third mechanism that may conduce earthquake hazard to increase civic capital is related to the individuals' emotional or psychological reaction to earthquakes. This mechanism should be particularly prominent when considering old earthquakes, that is natural events occurred in a period where the scientific knowledge was neither accurate nor widespread among the population. In Middle Age, for example, even nondestructive earthquakes generated panic among the general population and were perceived as a divine punishment. Medieval chronicles report that religious leaders had a crucial role in the process of reconciliation between individuals and God, further strengthening the power of bishops (see Belloc et al., 2016). We therefore conjecture that earthquakes had a twofold effect: on the one hand, they strengthened individuals' religious beliefs, which is a known driver of religious coping with adversity (Sinding Bentzen, 2019); on the other hand, they increased the incentive to set up new religious communities (i.e. build new churches), to improve the communities' ability to share risk (Ager and Ciccone, 2018). This latter mechanism creates a safety net that can also contribute to the accumulation of civic capital.

As the three mechanism outlined above may intersect with each other, we describe in the next session our proxies of civic capital that we use in isolation or combined into a single variable.

3. Data

In this section we describe the data employed in the empirical analysis. The unit of observation is an Italian municipality (*Comune*). To assess the relationship between earthquake hazard and civic capital, we combine several data sources to obtain municipal-level proxies. The use of municipal-level data means we have fine-grained information, as compared to typical studies of civic capital, which are often conducted at the regional or province level. Specifically, we use: (i) the presence of an organ donation association within a municipality; (ii) the rate of tax compliance; (iii) the number of Christian churches per square kilometer; and (iv) an index of civic capital derived from the principal components of the covariance matrix of (i), (ii), and (iii). We then match this information with historical and geo-referenced data on earthquakes dating from the year 1000 to 2015, as well as with a set of geo-morphological and historical characteristics of each municipality.

The subsections below describe the data sources and how we constructed the variables used in the empirical analysis. The full list of variables, including other control variables, their description, and their sources is reported in Appendix A.1. Table 2 presents summary statistics for all 8092 municipalities in our sample, where Panel A (resp. Panel B) refers to municipalities that have never been hit (have been hit at least once) by an earthquake.

[2] One could argue that in reality a high magnitude earthquake affects more than one community, implying that the shock is not idiosyncratic. However, one can reasonably assume that the intensity of damages caused by an earthquake is idiosyncratic within a community (e.g. a municipality).

3.1. Civic capital

The term “social capital” has been used to indicate a variety of concepts and debate over its definition is ongoing (Putnam, 1993). Here, we follow Guiso et al. (2011, 2016), and focus on proxies of the “shared beliefs and values that help a group overcome the free rider problem in the pursuit of socially valuable activities”. That is, we collect information on different dimensions of so-called *civic capital*.

First, as already proposed by Putnam (1993), we look at the presence of non-profit associations. It is possible, however, that, factors not directly related to purely altruistic motives may induce individuals to start a non-profit business; as such not all kinds of non-profit associations are necessarily a valid proxy of pro-social behavior. We accordingly draw on Guiso et al. (2016) and employ a dummy variable (*Organ donation*) that records the presence of an organ donation association (specifically, an “*Associazione Italiana per la Donazione di Organi*”, AIDO; the main association of this type in Italy) within a municipality. Since the decision to donate an organ does not result in a direct compensation for the donor, the concern that the presence of an AIDO may be related to economic motives is minimized. This variable therefore provides a valid proxy for the average municipal contribution to a common good.

Second, we consider individuals’ propensity to free-ride. Measuring this attitude can represent a challenge, particularly at a very disaggregated level. We overcome this issue by collecting information on payment of the TV licensing fee (*canone*), required of all households in Italy owning a telecommunication device (e.g., radio or television), independent of use. This data allows us to build a measure of local fiscal compliance (*Tax compliance*). That is, for each municipality, we use the share of households paying the annual licensing fee (Buonanno and Vanin, 2017; Buonanno et al., 2019), as reported by the Italian national public broadcasting company (RAI - *Radiotelevisione Italiana*). This information is a valid proxy of fiscal compliance for several reasons. First, the television fee is mandatory and accounts for a negligible part of RAI fiscal revenue.[3] Second, the fee amount is flat, small (about 9 euros per month), and independent of the number of household members. Finally, as in many other European countries during the period under study, public broadcasting programs were available independent of whether the TV owners actually paid the fee, essentially making its payment a pure public good contribution with almost no incentive to comply. Said differently, evading the licensing fee was very easy.[4]

Third, in line with the hypothesis that natural disasters can foster individuals’ propensity to engage in mutually insuring activities or find ways to cope psychologically with adverse events (Ager and Ciccone, 2018; Sinding Bentzen, 2019), we use the number of Catholic churches per square kilometer (*Churches*) as a measure of individuals’ religious coping and religious-driven cooperation. We gathered information on the presence of churches from the census of Italian Dioceses, while data on municipality surface come from the Italian National Institute of Statistics.[5]

Finally, we combine the above information and construct a synthetic measure of civic capital (*Civic capital*) using the first principal component of the covariance matrix of *Organ donation*, *Tax compliance*, and *Churches*. Fig. 1 presents the geographic distribution across the Italian territory of each measure of civic capital used in the analysis.

3.2. Earthquakes

As earthquakes are fairly distributed across all Italian municipalities, we proxy natural disasters hazard using information about earthquakes.[6] We build measures of earthquake hazard using data collected from the 2015 Parametric Catalogue of Italian Earthquakes (*Catalogo Parametrico dei Terremoti Italiani*, version CPTI15), assembled by the Italian National Institute for Geophysics and Volcanology (INGV) and publicly available on their website (Rovida et al., 2016).[7] The dataset contains information on the 4584 recorded earthquakes that occurred in Italy between the years 1005 and 2014, including the location, date, magnitude, and intensity of each seismic event. Since our outcome variables are measured in 2011, we exclude all the events that occurred after December 31, 2011 from our sample. For consistency, we also drop earthquakes without a geo-referenced epicenter location. The final dataset comprises 4354 events.

These events are decomposed along different dimensions to construct proxies of earthquake hazard using dummy variables that code the proximity to a seismic event. First, we use the georeferenced earthquake locations to establish whether or not a municipality has ever been hit. To this end, we employ a geographic information system (GIS) to assign a seismic event to each municipality by calculating the distance of an earthquake epicenter from a given municipal border. If the epicenter falls within the municipal borders, the distance is normalized to zero. Endowed with epicenter-border distances, we build dummy variables labeled *Quakes within d-km*, with $d \in \mathbb{R}$ being the distance measured in kilometers. Each variable takes a value of one if an earthquake epicenter ever falls within a circle of d-km radius from a municipal border, and zero otherwise. We set $d = 5$ as a baseline convention for our

3 Other studies have successfully used similar proxies to measure fiscal compliance in different European countries (e.g. Fellner et al., 2013; Berger et al., 2016).

4 In light of the heterogeneous compliance, the Italian government introduced new legislation, whereby household energy providers now levy the TV fee through their bills. This has made fee evasion *de facto* impossible, as doing so would imply a suspension of the energy provision.

5 The Italian Diocese census data is available at http://www.chieseitaliane.chiesacattolica.it/chieseitaliane/index.jsp. While Italy is home to other religious communities, Catholicism has historically been the dominant religion, justifying our specific focus on the share of churches of this denomination. The municipality surface data can be found at https://www.istat.it/it/archivio/156224.

6 Alternative proxies of natural disasters are comparatively not as informative. Proximity to a volcano, for example, would only be meaningful for a few provinces in southern Italy. Alternatively, focusing on hydrological hazard-prone areas would exclude many southern Italian municipalities (e.g. Diodato et al., 2019).

7 See https://emidius.mi.ingv.it/CPTI15-DBMI15/.

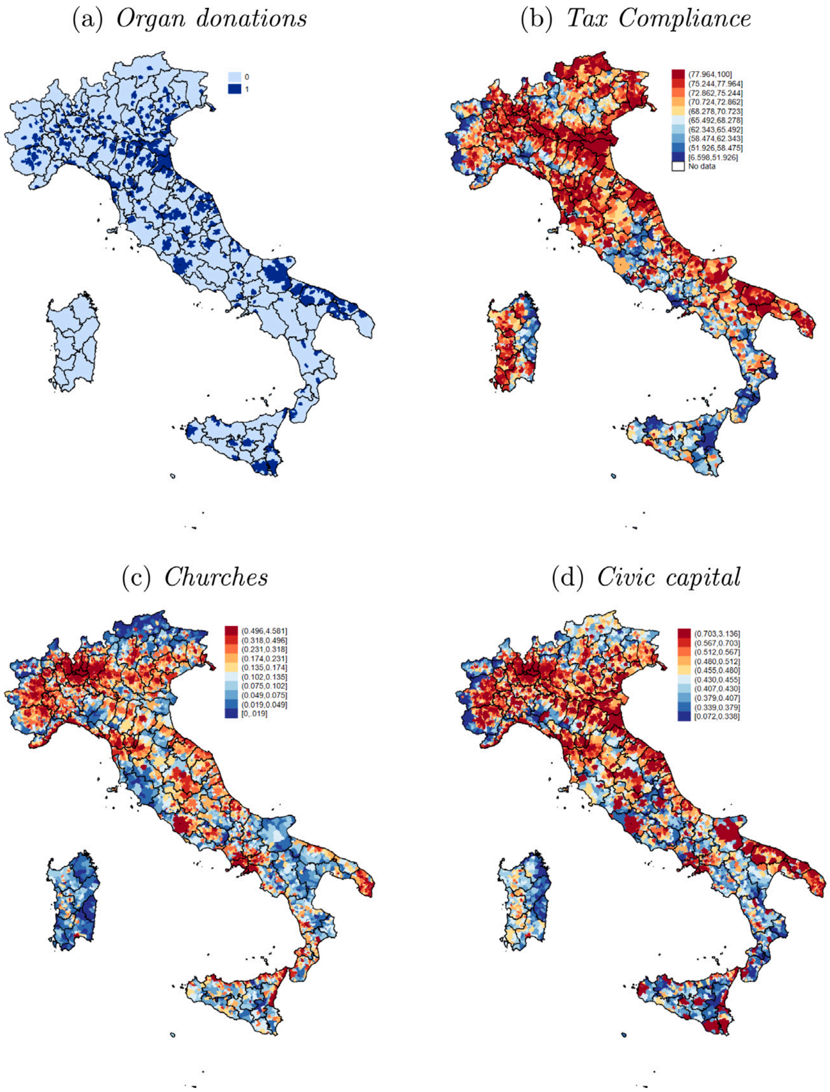

Fig. 1. Geographic distribution of civic capital outcomes.
Notes: This figure shows, for each municipality in the sample, the geographic distribution of the outcome variables used in the analysis.

estimates, and provide evidence that our results are robust to different distances, though the effect generally fades out as d exceeds 20 km.

Notably, our approach differs from that employed in previous studies using data on Italian earthquakes (Belloc et al., 2016; Masiero and Santarossa, 2020), in that we do not use the local seismic intensity to assign earthquakes to municipalities, but rather assign municipalities using the spatial distance between the epicenter and the municipal border. There are two reasons for this choice. First, we aim to minimize the obvious errors that arise in measuring earthquake sizes over a very long time span. Second, we want to address potential selection effects resulting from the comparison of municipalities that have never been hit by an earthquake to those located in very seismic areas. This strategy allows us to focus on the intensive margin of the effect, as we will construct measures of earthquake hazard focusing only on municipalities that have been hit at least once.

As a second earthquake hazard dimension, we consider the historical timing of seismic events. In particular, we explore whether the latter plays a role in the formation of individual beliefs and shared values, which, in turn, contribute to the accumulation of civic capital. To this end, we separate earthquake occurrences into three main blocks: (i) events that occurred before Italy's unification in 1861 (*Ancient quakes*); (ii) events between 1861 and 1945 (*Old quakes*); and (iii) events after 1945 (*Recent quakes*). *Ancient quakes*, *Old quakes*, and *Recent quakes* account for 28.5%, 31.5%, and 40% of the events in our sample, respectively. Fig. 2 displays the time distribution of the 4354 earthquakes included in the sample, where *Ancient quakes*, *Old quakes*, and *Recent quakes* are reported in light blue, blue, and dark blue, respectively.

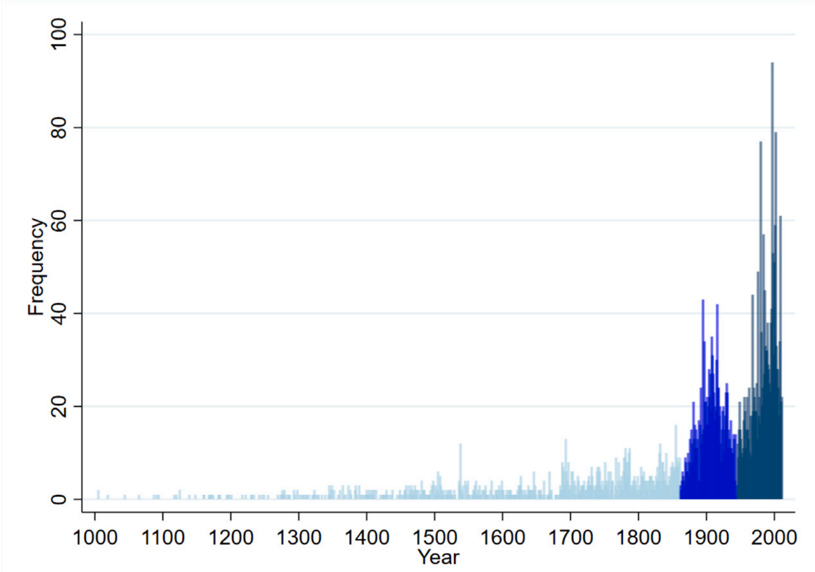

Fig. 2. Earthquakes distribution over time.
Notes: This figure displays the distribution over time of the earthquakes included in the sample. Each bar represents the total number of earthquakes that occurred in a given year. Events in light-blue occurred before 1861, those in blue between 1861 and 1945, and those in dark-blue after 1945. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Third, we study the effect of earthquake size, typically measured by two indicators: magnitude (Mw), and intensity (I). While Mw is an objective, standardized measure of earthquake size, I is subject to the evaluation of the observable impact on individuals, as defined by the United States Geological Survey.[8] While some scholars rely on intensity measures (e.g. Barone and Mocetti, 2014; Belloc et al., 2016; Masiero and Santarossa, 2020), here we adopt a magnitude-based approach for two reasons. First, the intensity of early events is frequently missing in the CPTI15, while their magnitude is always reported. Second, magnitude-based measures of earthquake hazard are less dependent on subjective evaluations of an earthquake's economic effect and, therefore, should be more reliable when comparing seismic events that are very distant across time.

Since earthquakes of very low Mw are hardly perceived by humans, the CPTI15 generally only reports earthquakes with a Mw equal or larger than 4.0, although some earthquakes with a lower Mw are also included when located in regions with very intense volcanic activity (e.g. the Etna and the Ischia-Phlegrean region, Rovida et al., 2016). To assess the impact of an earthquake's Mw, we divide seismic events between those that involve physical damage to individuals, and those that do not. Specifically, we use the dummy variable *High magnitude* to indicate events that have a Mw higher than 4.63, the threshold value above which a seismic event causes physical damages according to a conversion scale between intensity and magnitude.[9] We also perform sensitivity tests to check that our results are robust to different magnitude thresholds. Fig. 3 displays the magnitude distribution of the earthquakes included in the sample, with high-magnitude events accounting for roughly 31.3% of all events in our sample.

Finally, Fig. 4 summarizes the geographic distribution of the main variables used in our analysis, that is municipalities that have been hit by an earthquake within 5 km of their border: (i) at least once (Panel A); (ii) at least once by an earthquake of high magnitude (Panel B). Panels C and D show the geographic distribution of municipalities hit by old and ancient earthquakes of any magnitude and of high magnitude, respectively.

3.3. Other historical variables and municipal controls

To avoid that our measure of earthquake hazard affects the outcome variables through correlation with omitted municipal climatic, geographic, or even historical features, we also control for various other variables, with a specific focus on those potentially connected with the observed levels of civic capital and, at the same time, with the earthquake locations.

To account for differences in geomorphology, we control for municipal terrain ruggedness (*Ruggedness*), municipal elevation (*Altitude*), municipal surface (*Surface*) and share of mountainous terrain (*Mountainous*), information that is all available from the Italian National Institute of Statistics (ISTAT). While there is an obvious connection between these variables and other economic variables such as trade, agricultural productivity, and human mobility, rugged and mountainous terrains are notoriously close to Italian seismic hotspots. Moreover, to account for other factors that may affect certain economic outcomes (e.g. agricultural or

8 Available at https://earthquake.usgs.gov.

9 See Rovida et al. (2016) and Scordilis (2006) for a technical discussion of this topic.

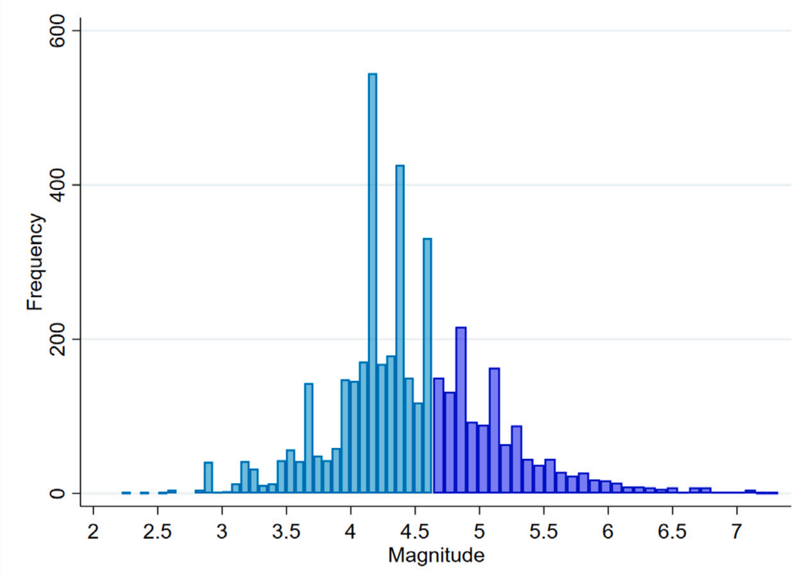

Fig. 3. Earthquakes distribution by magnitude.
Notes: This figure displays the distribution of earthquakes by magnitude (Mw). The frequency of seismic events with magnitude below (resp. above) 4.63 Mw is reported in light-blue (resp. blue). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

breeding activities), we also control for the distance from the sea (*Sea distance*), again available from ISTAT, and a suitability index for rain-fed cereals (*Land suitability*) constructed using data on crop-specific agro-ecological suitability, available from the IIASA-FAO Global Agro-Ecological Zones project (*GAEZ*).[10]

We also control for certain socio-economic and demographic characteristics that may be correlated with our outcome variables. Note that in order to address potential "bad control" issues – due to the simultaneous measurement of outcome variables and control variables – we focus on the pre-existing municipal topography. Specifically, we include the municipal distance from the closest Ancient Roman road (*Distance Roman Road*), available from the Digital Atlas of Roman and Medieval Civilizations (DARMC), the estimated total population in 1100 AD (*Population 1100*), taken from Klein Goldewijk et al. (2010), and a dummy variable equal to one if the municipality was the seat of a bishop by the year 1000 or borders with one of these towns (we obtain this information from Guiso et al., 2016).

Finally, we also include contemporary controls to account for potential omitted variable bias. We include a dummy variable for the 25 most populated municipalities (*Big cities*).[11] Appendix A.1 provides the full list of variables used in our analysis, together with their sources. With this wealth of information, we are now ready to empirically assess our hypotheses.

4. Baseline evidence

In this section, we presents a preliminary assessment of whether and how exposure to earthquake hazard affects the level of municipal civic capital. As discussed above, we hypothesize that long-run exposure to earthquake hazard favored pro-social behavior, leading to the accumulation of civic capital. To verify our hypotheses, we thus exploit the heterogeneous distribution of earthquakes across Italy. Formally, we estimate the following baseline specification

$$Civic\ Capital_{mp} = \alpha + \beta Quakes_{mp} + \gamma_p + \mathbf{X}'_{mp}\delta + \varepsilon_{mp} \tag{1}$$

where: (i) $Civic\ Capital_{mp}$ is a measure of civic capital in municipality m of province p; (ii) $Quakes_{mp}$ is a measure of earthquake hazard in municipality m of province p; (iii) γ_p is a province fixed effect; and (iv) $\mathbf{X}'_{mp}$ includes a wealth of geographical and historical exogenous control variables measured at the municipal level. The inclusion of province fixed effects allows us to identify β using within-province variation. This implies that our exercise compares municipalities likely to be exposed to a similar level of earthquake hazard. Moreover, since the occurrence of an earthquake is, by definition, unpredictable, measures of earthquake hazard should be treated as exogenous with respect to the outcome variable.

[10] More information about the FAO-GAEZ project can be found at http://www.gaez.iiasa.ac.at/.

[11] Rome, Milan, Naples, Turin, Palermo, Genoa, Bologna, Florence, Bari, Catania, Venezia, Verona, Messina, Padoa, Trieste, Taranto, Brescia, Prato, Reggio Calabria, Modena, Parma, Reggio nell'Emilia, Perugia, Livorno, Ravenna and Cagliari.

Table 1
Baseline estimates with earthquake dummy.

Panel A. Organ donation	(1)	(2)	(3)	(4)
Quakes within 5 km	0.0243***	0.0205***	0.0201***	0.0187***
	(0.0045)	(0.0044)	(0.0050)	(0.0050)
	[0.0047]	[0.0046]	[0.0053]	[0.0053]
R^2	0.1866	0.1993	0.1992	0.2173
Panel B. Tax compliance				
Quakes within 5 km	0.0121***	0.0099**	0.0105***	0.0107***
	(0.0021)	(0.0021)	(0.0022)	(0.0022)
	[0.0042]	[0.0040]	[0.0040]	[0.0039]
R^2	0.4510	0.4659	0.4661	0.4666
Panel C. Churches				
Quakes within 5 km	0.0296***	0.0267***	0.0291***	0.0278***
	(0.0064)	(0.0063)	(0.0065)	(0.0065)
	[0.0095]	[0.0095]	[0.0107]	[0.0107]
R^2	0.2955	0.3095	0.3097	0.3171
Panel D. Civic capital				
Quakes within 5 km	0.0377***	0.0325***	0.0338***	0.0323***
	(0.0049)	(0.0048)	(0.0052)	(0.0051)
	[0.0064]	[0.0064]	[0.0075]	[0.0075]
R^2	0.2551	0.2760	0.2763	0.2931
Observations	7967	7938	7938	7938
Province FE	✓	✓	✓	✓
Geographic Controls	✓	✓	✓	✓
Historic Controls	×	✓	✓	✓
Contemporary Controls	×	×	×	✓
Earthquakes Sample	Full sample	Full sample	High Magnitude	High Magnitude

Notes: This table reports the results of OLS estimates on a cross-section of observations for all the Italian municipalities in the sample. The dependent variables are (Panel A) a dummy indicating the presence of an organ donation associations; (Panel B) the rate of tax compliance of the Italian public TV's fee; (Panel C) the number of churches per square kilometer; (Panel D) a measure of Civic capital obtained through the principal components analysis of the Panels (A)-(C) dependent variables covariance matrix. Geographic controls include: altitude, ruggedness, surface, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the municipal distance from the closest Ancient Roman road, municipality population in 1100 AD and a dummy equal to one if the municipality was the seat of a bishop by the year 1000 or it borders with one of these towns. Contemporary controls include a dummy for the 25 biggest municipalities in 2011. Robust standard errors in parentheses. Conley's standard errors corrected for spatial dependence with threshold distance of 50km in square brackets. ***, ** and * refer to 10%, 5% and 1% significance, respectively. Statistical significance is indicated employing the Conley's standard errors.

4.1. Basic correlation

Table 1 reports the results of OLS estimations of Eq. (1), based on a cross-section of observations for all the municipalities in the sample. The measure of earthquake hazard is a dummy variable, i.e. *Quakes within 5* km, which is equal to one when a municipal border is within 5 km of an earthquake's epicenter, and zero otherwise. All regressions include province fixed effects, implying that regression coefficients are identified for within-province variation.

To account for possible heterogeneous dynamics of the error terms, we report two different standard errors. First, a robust standard error reported in parentheses. Second, we account for potential spatial correlation of the error terms in an unknown form and report, in square brackets, standard errors computed according to Conley (1999). In this case, the threshold distance after which the arbitrary dependence disappears is fixed at 50 km.[12][13]

In line with our research hypothesis, all estimated coefficients presented in columns (1) and (2) of Table 1 are positive, significant at the 1% confidence level. To minimize the risk that within-province variations in civic capital are related to differences in other variables, we also include geographic, historical and contemporary control variables. Geographic control variables include terrain ruggedness, municipal surface, the share of mountainous terrain, municipal altitude, an index of land suitability, and distance from the sea. Historic control variables include the municipal distance from the closest Ancient Roman road, the estimated total population in the year 1100 and whether a municipality has been a seat of a bishop by the year 1000 AD. Contemporary controls include a

[12] For brevity, we do not report additional estimates showing that our estimates are still highly significant and qualitatively similar when we use different thresholds of spatial dependence (i.e. 25 km, 75 km, 100 km). We compute Conley standard errors using the acreg command for Stata by Colella et al. (2019).

[13] In A.4 we estimate a spatial model by means of the generalized spatial two stage least squares (GS2SLS) estimator of Kelejian and Prucha (1998). Results are presented in Table A.3. We implement a spatial error model, a spatial autoregressive model and a model that combines the two by considering both a spatial lag and a spatial error structure. Allowing for a spatial structure in our data does not alter our baseline estimates. Moreover, in appendix A.5 we explore alternative clustering (province level or regional level) for all our analysis, but we do not observe much differences with respect to the inference based on Conley's method.

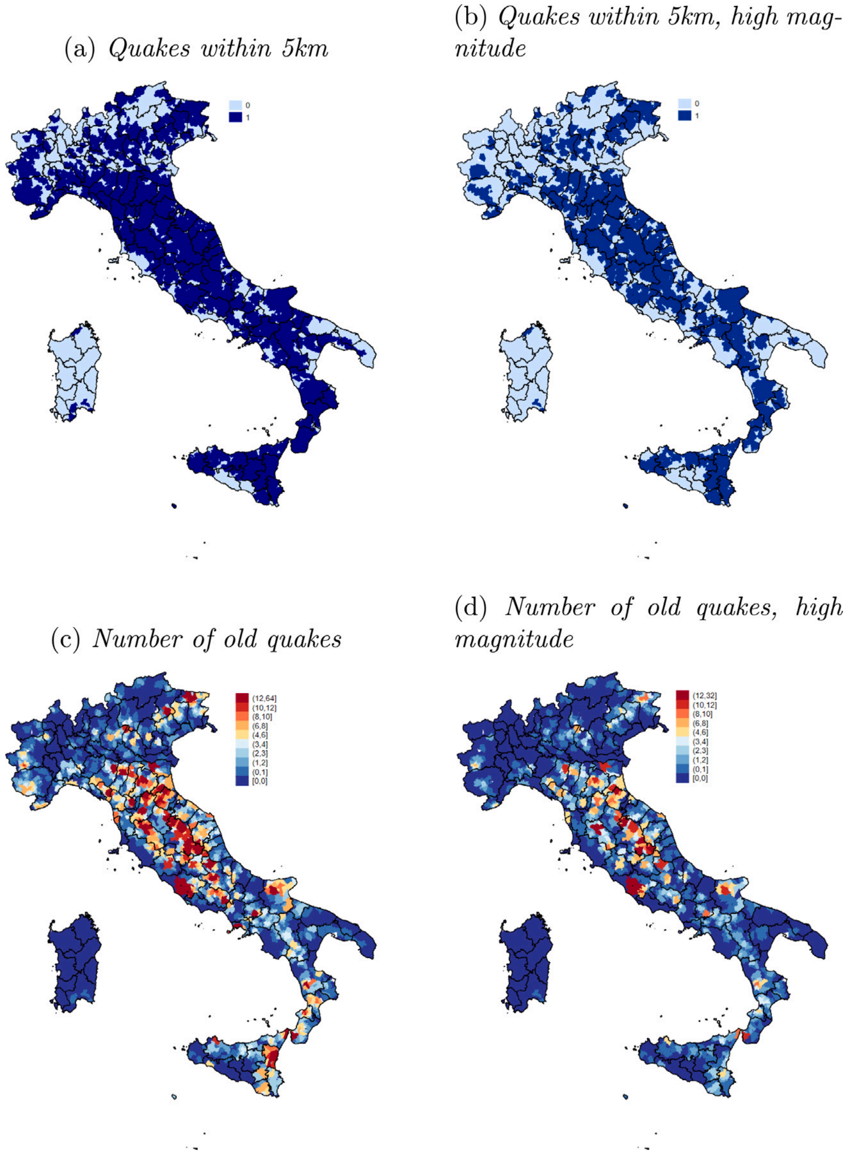

Fig. 4. Geographic distribution of Earthquakes.
Notes: This figure shows the geographic distribution of municipalities hit by an earthquake occurred within 5 km from his boundaries of any intensity (a) and at least 4.63 Mw (b). Panels (c) and (d) show the geographic distribution of municipalities hit by old and ancient earthquakes of any intensity and above 4.63 Mw, respectively.

dummy for the biggest 25 cities (*Big cities*). Our estimates remain highly significant and the magnitude of the coefficients is barely affected, suggesting that our results are not driven by omitted variables.

While the estimates in columns (1) and (2) use all 4354 events in our sample, in column (3) and (4) we also report the estimates based on a restricted sample of 1754 earthquakes of high magnitude, i.e., earthquakes whose magnitude is higher than 4.63 Mw. This strategy allows us to address possible concerns that our results are mechanically driven by events that do not cause physical damages. As reported in column (3) and (4), our estimates are still highly significant and qualitatively similar to those of columns (1) and (2).

Our baseline estimates support our research hypothesis by showing a positive association between earthquake hazard and the accumulation of civic capital. As an additional check, we also control for possible spatial effects. Because the effects of earthquakes (obviously) do not follow the administrative boundaries of municipalities, there may be relevant spatial spillovers from one municipality to another. Overlooking these potential spillovers may bias our estimates or reduce the efficiency of our estimates.

To address this potential concern, in appendix A.4 we estimate a spatial model using a generalized spatial two-stages least squares (GS2SLS) model, allowing the variation in earthquake hazard to have potential spatial spillovers from a given municipality to its neighboring municipalities. Our preliminary results remain stable after the inclusion of this possibility.

Table 2
Summary statistics.

	Panel A: Non-Hit Municipalities					Panel B: Hit Municipalities					
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	t
Organ donation	1861	0.040	0.197	0	1	1595	0.086	0.280	0	1	−5.5919***
Tax compliance	1861	0.654	0.115	0.089	1	1593	0.658	0.109	0.186	1	−1.0431
Churches/sq. km	1840	0.194	0.252	0	2.727	1584	0.192	0.232	0	2.941	0.2522
Civic capital	1840	0.489	0.212	0.072	1.858	1584	0.520	0.254	0.126	1.779	−3.8766***
Sea distance (km)	1861	62.218	51.819	0	230.344	1593	59.132	48.137	0	225.03	1.8026*
Ruggedness	1860	223.70	208.72	0.894	1029.63	1593	231.01	194.40	0.990	1035.62	−1.0584
Surface	1861	38.478	45.665	0.15	474.46	1593	55.928	71.716	1.7	1307.71	−8.6469***
Altitude	1861	548.648	509.912	0	2845	1593	595.035	469.229	0.5	2560.5	−2.7646***
Mountainous	1861	47.837	48.105	0	100	1593	52.480	47.228	0	100	−2.7901***
Land suitability	1841	5.253	1.191	2	8.875	1585	5.256	1.154	2	8.152	−0.0828
Distance Roman Road	1841	7.735	7.534	0	41.277	1585	7.773	7.638	0	43.005	−0.1459
Population 1100	1857	710.70	2866.50	2.686	104197.8	1595	1223.15	7550.88	0.601	283997.4	−2.7064***
Bishop	1832	0.358	0.479	0	1	1585	0.424	0.494	0	1	−3.9821**
Big cities	1862	0.001	0.023	0	1	1595	0.011	0.106	0	1	−4.2711***

Notes: This table reports summary statistics of the variables used in our analysis. Panel A refers to all the non-hit municipalities in the sample. Panel B refers only to the municipalities that have been hit at least once in their history by an earthquake with magnitude above 4.63 Mw within 5 km.

5. The impact of earthquake hazard on civic capital

5.1. Neighbor-pair fixed effect estimates

Thus far we have documented a robust positive correlation between earthquake hazard and civic capital. Although the exact geo-coordinates of an earthquake epicenter are random, seismic areas are not randomly distributed across Italy but rather geographically concentrated along a few fault systems (e.g., the Central Apennines). To make sure that systematic differences in seismology do not pick up the effects of certain other characteristics that may be relevant for civic capital accumulation, we provide estimates that rely on province fixed effects and municipality level controls. More specifically, we expand the analysis by exploiting variations in earthquake hazard across directly neighboring municipalities. The neighbor-pair fixed effects estimator shares features with a matching and regression discontinuity design, and compares hit municipalities to non-hit neighboring ones (Acemoglu et al., 2012; Buonanno et al., 2015). This empirical strategy offers two main advantages. First, it allows us to control directly for unobservables that are common across adjacent municipalities by including neighbor-pair fixed effects in the regression model. Second, we can compare neighboring municipalities for which the probability of been treated as hit by an earthquake is similar within the pair.

For the estimation, we use the same dummy variable described in Section 4.1 (*Quakes within 5* km) to divide Italian municipalities in hit and non-hit. *Quakes within 5* km is calculated using the restricted sample of high magnitude events, as the inclusion of weak earthquakes could bias the pair definition. Reassuringly, using the full sample of events hardly affects our estimates, as show in Table A10 (with the notable exception of Churches).[14] We then restrict our analysis to the 1595 hit municipalities (red) that have a non-hit adjacent municipality and these 1862 non-hit adjacent municipalities (blue). Fig. 5 displays hit municipalities and their neighbors. The light gray municipalities are excluded from the analysis as they and their neighbors have never been hit by an earthquake. Gray municipalities are also excluded because, even if they have been hit by an earthquake, they do not border any non-hit municipality.

Table 2 reports the summary statistics for the variables used in the analysis. Specifically, Panel A of Table 2 presents statistics for the 1862 non-hit adjacent municipalities, while Panel B displays statistics for 1595 hit municipalities. The t-statistics refer to the differences between the variable means in Panel A and Panel B.

Formally, we estimate the following model by means of OLS:

$$Civic\ Capital_h = \phi_{hn} + \beta Quakes_h + \mathbf{X}_h'\gamma + \varepsilon_h \qquad h \in H \tag{2}$$

$$Civic\ Capital_n = \phi_{hn} + \beta Quakes_n + \mathbf{X}_n'\gamma + \varepsilon_n \qquad n \in N(h) \tag{3}$$

where H is the set of hit municipalities, indexed by h, and $N(h)$ is the set of non-hit neighboring municipalities; h and n indicate hit and non-hit municipalities, respectively, while ϕ_{hn} represents common unobservables for the pair (h, n), and ε_h and ε_n represent hit and non-hit municipality specific error terms, respectively.

We present the results of the estimates that include neighbor-pair fixed effects in Table 3. For consistency with the baseline results, we progressively add control variables and show both robust and Conley's standard errors in parentheses and square brackets, respectively. Column 1 shows that, in a univariate regression, the estimated coefficients on *Quakes within 5* km are always highly significant. As expected R^2 increases a lot after the inclusion of neighbor-pair fixed effects (column 2), meaning that we are capturing a lot of unobserved heterogeneity at the pair level. In our more conservative specification (column 4) a one standard deviation

[14] Using the dummy *Quakes within 5* km over the full sample to define hit and not hit municipalities produces a different set of pairs with respect to the high magnitude sample. We do not report in Table 1 estimates using the full sample of earthquakes exactly because estimates are not comparable.

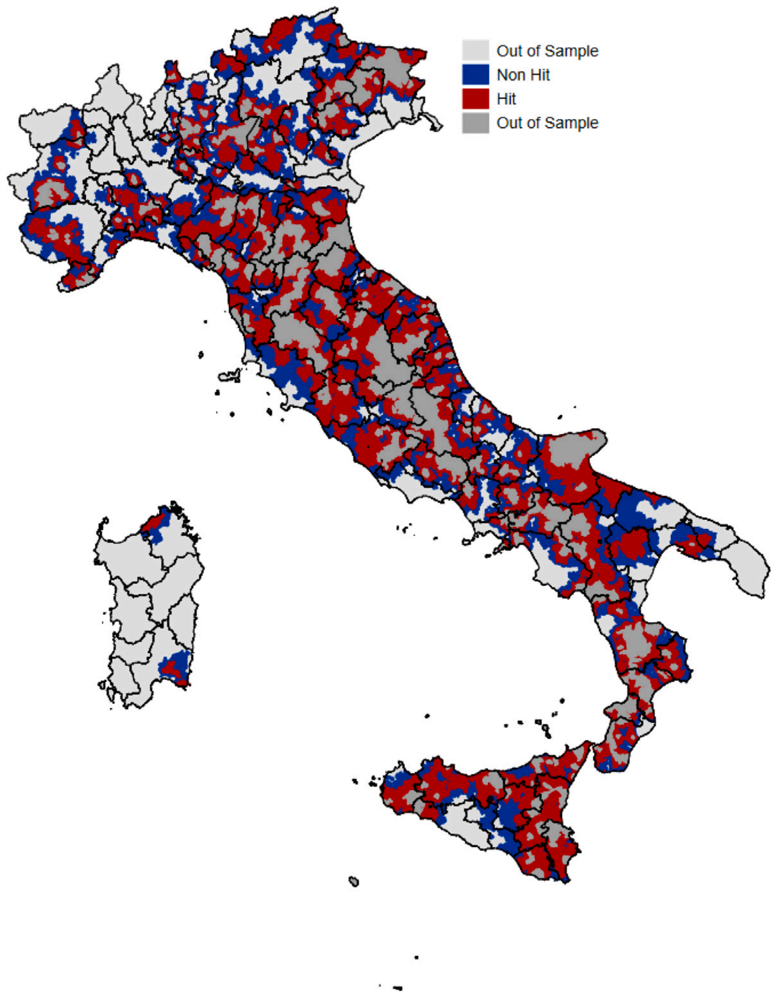

Fig. 5. Hit Municipalities and their Neighbors.
Notes: Light gray municipalities are excluded from the analysis as they and their neighbors have never been hit by an earthquake. Blue municipalities are the 1862 non-hit municipalities that have an adjacent (red) hit municipality (1595 in number). Gray municipalities are also excluded from the analysis because, even if they have been hit by an earthquake, they do not border any non-hit municipality. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

increase in the earthquake hazard leads to an increase in *Civic capital* by 6.7% of a standard deviation. For robustness, we perform sensitivity analysis using different definition of high magnitude events presented in figures A4 and A5. Specifically, we change the Mw threshold according to different percentiles of magnitudes distribution.[15] Results are barely affected.

Overall, these results further support the hypothesis that earthquake hazard significantly contributed to the accumulation of municipal civic capital. This conclusion rests, however, on the identifying assumption that, within a pair and controlling for what we can observe, earthquake hazard is not correlated with any unobserved civic capital determinants.[16]

5.2. Alternative specifications

In this section, we perform several alternative specifications. First, we decompose the results of our baseline estimates along the spatial dimension, namely allowing for the effect of earthquake hazard to vary with the distance between an epicenter and a

[15] The current threshold, 4.63 Mw, corresponds to the 68th percentile of the magnitudes distribution.

[16] To provide support for this assumption we employed the δ statistics proposed by Oster (2019). The δ statistic measures by how many times unobservables should be correlated with earthquake hazard to bring down to zero estimated coefficients, given that these unobservables can only explain less than 25% of civic capital variability (Oster, 2019). The δ statistics reported in Table 3 generally support our exogeneity assumption. For example, with reference to the comparison between columns 4 and 1, a $\delta = 1.72$ for β_4 says that if the unobservable characteristics (which explain only 25% of the variability of the outcome) could be included, they would have to be about 2 times more correlated with earthquake hazard than the observed ones to kill our results.

Table 3
Neighbor-pair fixed effect estimates.

Panel A. Organ donation	(1)	(2)	(3)	(4)
Quakes within 5 km (β_1)	0.0896***	0.0897***	0.0438***	0.0372***
	(0.0065)	(0.0062)	(0.0058)	(0.0057)
	[0.0148]	[0.0135]	[0.0108]	[0.0103]
R^2	0.0248	0.5584	0.6347	0.6537
Oster δ for $\beta_1 = 0$			1.27	1.05
Panel B. Tax compliance				
Quakes within 5 km (β_2)	0.0130***	0.0132***	0.0088***	0.0090***
	(0.0026)	(0.0017)	(0.0018)	(0.0018)
	[0.0036]	[0.0030]	[0.0033]	[0.0033]
R^2	0.0034	0.7776	0.7918	0.7920
Oster δ for $\beta_2 = 0$			4.94	5.21
Panel C. Churches				
Quakes within 5 km (β_3)	0.0170**	0.0153**	0.0157**	0.0114*
	(0.0054)	(0.0039)	(0.0039)	(0.0038)
	[0.0074]	[0.0063]	[0.0063]	[0.0060]
R^2	0.0013	0.7383	0.7593	0.7715
Oster δ for $\beta_3 = 0$			13.48	4.87
Panel D. Civic capital				
Quakes within 5 km (β_4)	0.0750***	0.0744***	0.0417***	0.0353***
	(0.0060)	(0.0052)	(0.0049)	(0.0048)
	[0.0119]	[0.0106]	[0.0092]	[0.0087]
R^2	0.0205	0.6316	0.6942	0.7154
Oster δ for $\beta_4 = 0$			2.10	1.72
Sample: High magnitude				
Observations	7573	7573	7560	7560
Neighbor-pair FEs	×	✓	✓	✓
Geographic Controls	×	×	✓	✓
Historic Controls	×	×	✓	✓
Contemporary Controls	×	×	×	✓

Notes: This table reports the results of OLS estimates on a cross-section of observations for those municipalities that form a couple in which a municipality have been hit at least once by an earthquake and its neighbor has not. Each municipality in a pair shares a common pair fixed effect. The dependent variables are (Panel A) a dummy indicating the presence of an organ donation associations; (Panel B) the rate of tax compliance of the Italian public TV's fee; (Panel C) the number of churches per square kilometer; (Panel D) a measure of Civic capital obtained through the principal components analysis of the Panels (A)-(C) dependent variables covariance matrix. Geographic controls include: altitude, ruggedness, surface, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the municipal distance from the closest Ancient Roman road, municipality population in 1100 AD and a dummy equal to one if the municipality was the seat of a bishop by the year 1000 or it borders with one of these towns. Contemporary controls include a dummy for the 25 biggest municipalities in 2011. Robust standard errors in parentheses. Conley's standard errors corrected for spatial dependence with threshold distance of 50km in square brackets. ***, ** and * refer to 10%, 5% and 1% significance, respectively. Statistical significance is indicated employing the Conley's standard errors.

municipal border. Second, we present the results of our estimates based only on the subsample of hit municipalities, to see whether the total number of seismic events plays a role in the correlation between hazard rate and civic capital. Third, and only for hit municipalities, we decompose the effect of seismic events along the following three dimensions: (i) distance from the epicenter; (ii) timing of the seismic event; and (iii) magnitude.

5.2.1. Distance from the epicenter

We start by exploring whether the distance from an earthquake epicenter matters for the association between civic capital and earthquake hazard. Fig. 6 displays the results of the estimations reported in column (4) of Table 1, calculated for different distances. Specifically, the main explanatory variable is a dummy variable *Quakes within d-km* that is equal to one when a municipal border is within $d \in \{0, 1, 2, \dots, 15\}$ kilometers from at least one earthquake's epicenter, and zero otherwise.

The estimated coefficients are positive and statistically significant for all measures of civic capital only within the first 5–10 km. They then gradually approach zero and become statistically not significant as the distance grows. Intuitively, this finding suggests that individuals are more likely to engage in pro-social activities if they are close to an earthquake epicenter. Remarkably, the highest coefficient is estimated at a distance of zero, implying that civic capital is higher in those municipalities directly affected by an earthquake.[17]

[17] These findings are not a mechanical result of the shrinkage of the non hit municipalities group as d increases, at least for distances lower than 15 km. Table A2 in Appendix A.3 shows that up to 15 km, not less than 17% of the municipalities are treated as non hit by an earthquake.

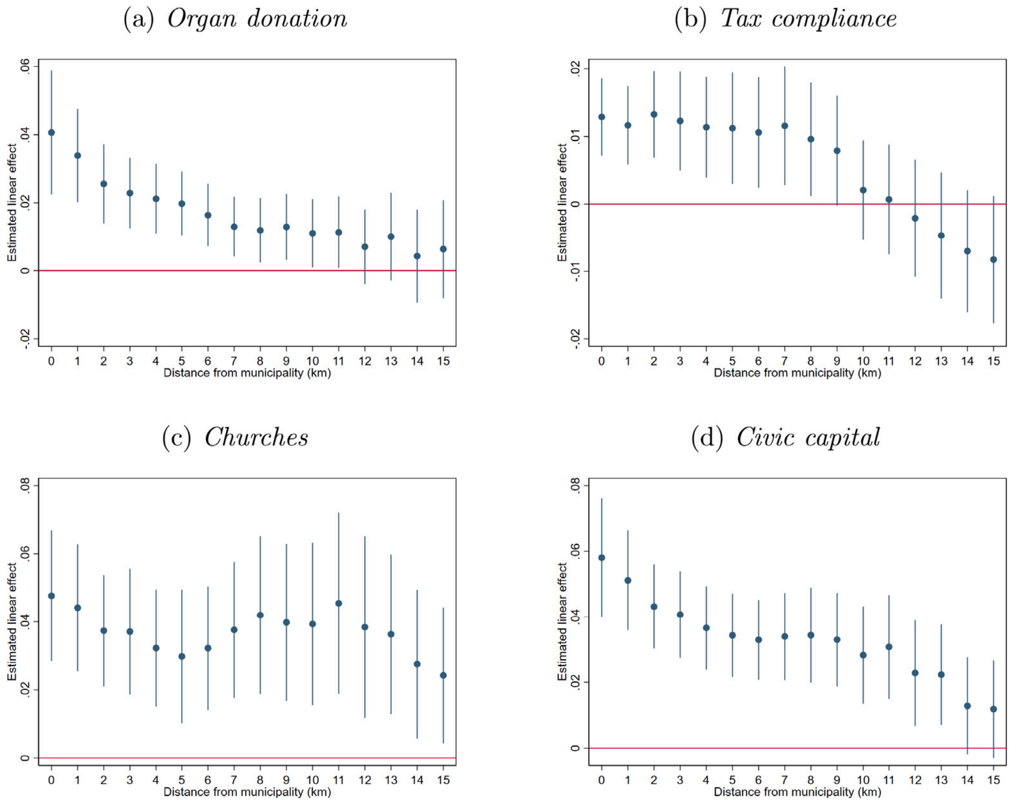

Fig. 6. Spatial decomposition of linear prediction.
Notes: This figure displays the estimated linear coefficients of OLS regressions with measures of civic capital as dependent variable, a dummy variable equal to one if an earthquake occurred within $d \in \{0, 1, 2, \ldots, 15\}$ km from a municipality, and zero otherwise, as main independent variables, and the sets of control variables as in Table 1.

5.2.2. Treated municipalities

Hit and non-hit municipalities might systematically differ, such that our estimates could suffer a distorsion due to selection bias. To address this concern, we explore the effect of earthquake hazard on hit municipalities only.

Fig. 7 displays the estimated coefficients of regressions that focus only on the subsample of municipalities that have been hit at least once by an earthquake within $d \in \{0, 1, 2, \ldots, 15\}$ kilometers. Contrary to those displayed in Fig. 6, since we are interested here in hit municipalities, we use *N. Quakes within d-km*. That is, the total number of all seismic events located within d kilometers of the municipal border. This approach allows us to estimate the intensive margin of the earthquake hazard on our measures of civic capital.

The positive association between measures of civic capital and earthquake hazard remains stably significant, and mostly concentrated within the first 5 km from an epicenter. This preliminary evidence suggests that the effect of earthquake hazard is heterogeneous among hit municipalities, as those municipalities that have been hit more frequently display on average a higher level of civic capital. This evidence also corroborates the idea that the results presented in Sections 4.1 and 5.1 are unlikely driven by unobservables that make hit and non-hit municipalities systematically different.

5.2.3. Marginal effect

We further analyze the effect of having experienced more seismic events by looking at the marginal effect of *N. Quakes within* 5-km.[18] Fig. 8 displays the marginal effects of the regression coefficients, for each of our measures of civic capital as dependent variables. The marginal effect is statistically significant mostly around 20 seismic events for all civic capital measures, suggesting that the level of civic capital increases only slightly for municipalities that have only occasionally been hit by earthquakes. As the number of events increases, the marginal effect reduces and becomes less statistically significant, implying that the relation between earthquake frequency and civic capital is concave.

[18] In technical terms, we estimate the marginal effects of a third-order polynomial regression with *N. Quakes within* 5-km as the main independent variable, and the same set of control variables as used in column (4) of Table 1.

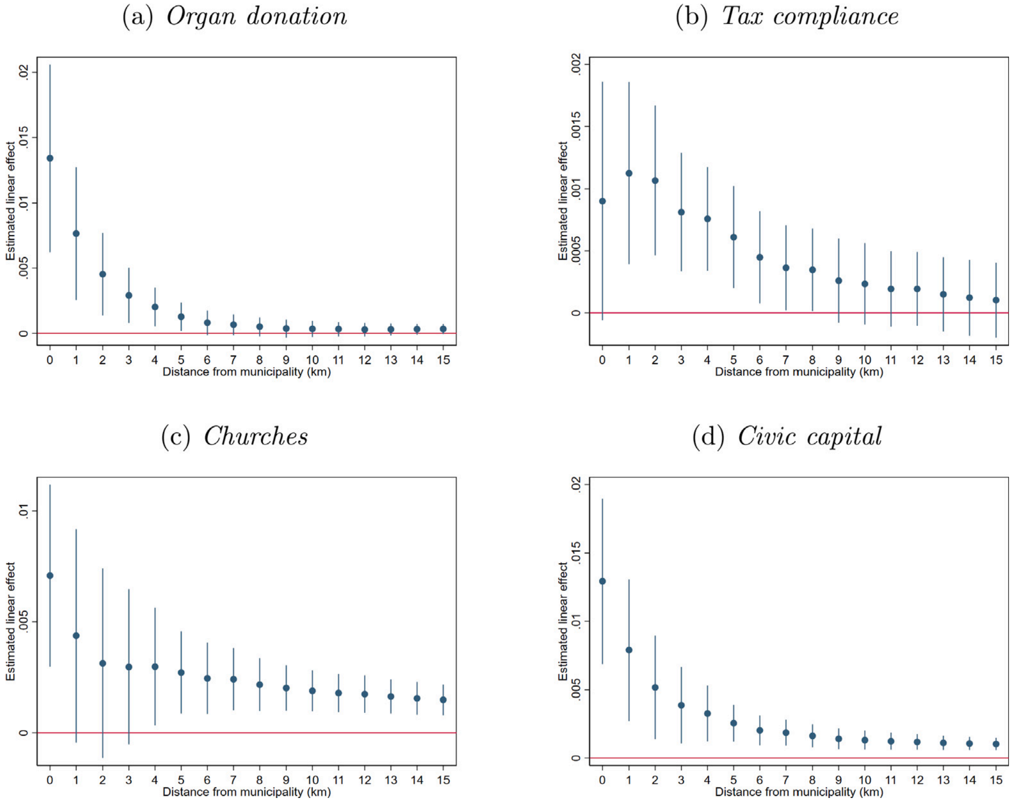

Fig. 7. Spatial decomposition of linear prediction.
Notes: This figure displays the estimated linear coefficients of OLS regressions with measures of civic capital as dependent variable, the total number of all seismic events located within $d \in \{0, 1, 2, \ldots, 15\}$ km from a municipal border (*N. Quakes within d-km*), as main independent variables, and the sets of control variables as in Table 1. Coefficients are estimated using subsample of municipalities that have been hit at least once by an earthquake within $d \in \{0, 1, 2, \ldots, 15\}$ km.

An inspection of Fig. 8 suggests that the estimated marginal effects gradually approach zero roughly after 30/40 seismic events. As our sample covers about 1000 years, this observation implies that this frequency is reached, on average, at every generation (every 25/30 years). Arguably, because every generation is on average hit by at least one seismic event, individuals may thus learn and internalize how to manage earthquake hazard. Therefore, one can reasonably believe that additional earthquakes do not contribute further to the accumulation of civic capital. This finding is in line with Giuliano and Nunn (2020), as the main driver of the accumulation of civic capital is the stable exposure to frequent seismic events, rather than to extreme occasional events.

5.2.4. Earthquakes timing

We conclude our robustness checks by examining whether the heterogeneous effects of earthquake hazard may be explained by the historical timing of earthquake occurrences.

Table 4 reports the results of these estimates, based on the subsample of hit municipalities, where the control variables are the same as in Table 1 and standard errors are computed following the Conley's method (Conley, 1999) with a threshold of 50 km.[19]

Panel A reports estimates where we decompose the number of earthquakes along the timing dimension and regress our measures of civic capital on the number of earthquakes that occurred after the Second World War up until 2011 (*N. Recent quakes*); between Italian unification in 1861 and the second world war (*N. Old quakes*); and before Italian unification *(N. Ancient quakes*). Our time-decomposition reveals that most of the effect of earthquake hazard on civic capital is explained by old or ancient earthquake variation, suggesting that higher levels of civic capital are likely the result of social norms that individuals, or more generally societies, have internalized over very long time spans.

This intuition is corroborated by the results reported in Panel B. Here we report the coefficients obtained from the same regression model as in Panel A, but based on a restricted sample of 1754 earthquakes of high magnitude, i.e., earthquakes whose magnitude is higher than 4.63 Mw. The estimated coefficients in this case are still statistically significant and remain stable in their sign and size

[19] For brevity, we omit alternative estimates producing similar results, which test the sensitivity of the Conley's threshold (i.e., set at 25, 75 and 100 km from the municipality, respectively).

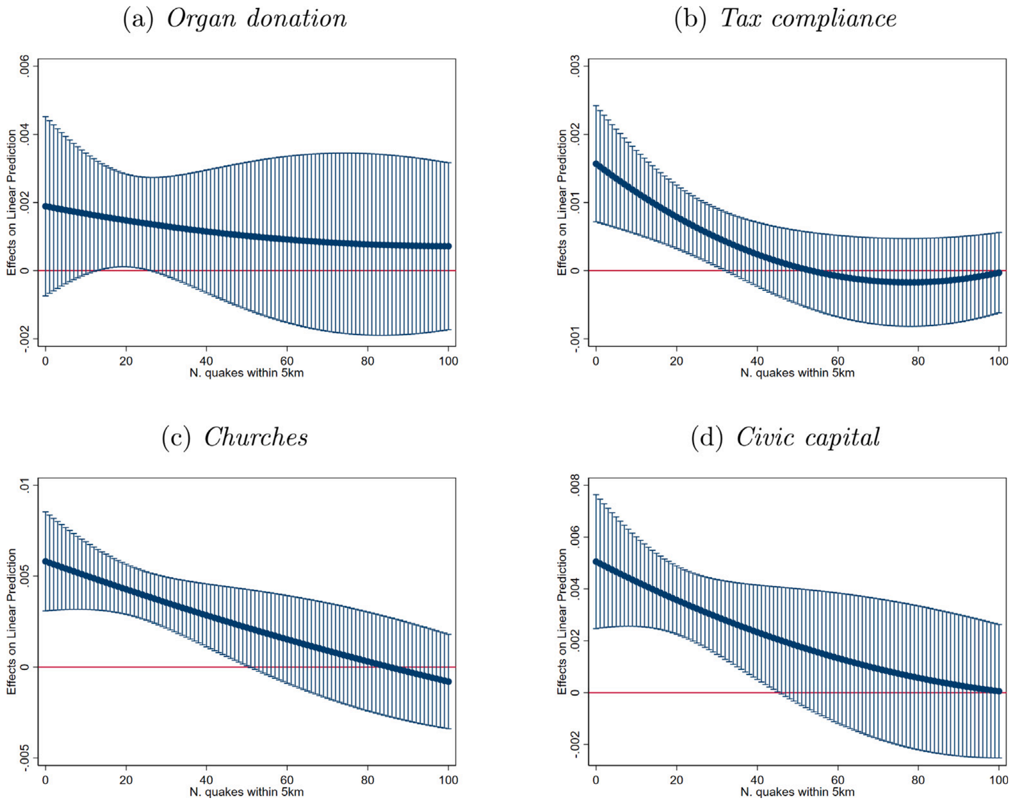

Fig. 8. Marginal effect of linear prediction.
Notes: This figure displays the marginal linear effect of a third degree polynomial OLS regression with measures of civic capital as dependent variables, the number of earthquakes that occurred within 5 km from a municipality as main independent variables, and the sets of control variables as in Table 1.

for old and ancient seismic events. Table A9 shows the same estimates of Table 4, but using the average frequency of occurrence (i.e, earthquake hazard) for each time period.[20] This alternative definition does not affect our findings. However, although we tried to offer a rationale for the definition of each time period (i.e. *Recent quakes*, *Old quakes*, *Ancient quakes*), their definition is still arbitrary. Figures A6, A7, A8 and A9 tests the sensitivity of our results to alternative definitions of *Ancient quakes*. Reassuringly, our predictions are not affected by this change.

Our findings about timing and magnitude complement our baseline analysis in showing the potential existence of a causal link between earthquake hazard and civic capital, mainly driven by seismic events of high magnitude that occurred in the past.[21]

5.2.5. Earthquakes and political outcomes

In this section, we test the possible effect of long-run exposure to earthquakes on political outcomes. We test two potential channels. First, earthquakes may impact the political component of civic capital, measured by the voting turnout. We argue that communities exposed to earthquakes should develop a higher civic duty with respect to voting participation. Second, repeated exposure to earthquakes' damages may cause a higher demand for welfare state and social spending to cope with present and future seismic events. Table A8 reports estimates for the same regression model used in panel b, Table 4, but using political outcome variables rather than usual civic capital measures. In column 1 we use as measure of political participation the voting turnout for the 1948 Italian elections, while we measure preferences for welfare state and social spending by using the share of votes for the *Fronte Popolare*.[22] We find a positive and significant impact of the number of *Old quakes* on voting turnout, while we do not find any effect of the share of votes for the left coalition. In column 2 we replicate the same exercise for modern elections (2008 national

[20] In particular *Hazard recent quakes* is the sum of all quakes occurred after 1945 until 2011 and divided by the time window (66 years). *Hazard old quakes* is the sum of all quakes occurred between 1861 until 2945 and divided by the time window (84 years). *Hazard ancient quakes* is the sum of all quakes occurred before 1861 and divided by the time window (856 years).

[21] In Appendix A6 we further test the robustness of results discussed in Section 5.2.4.

[22] 1948 were the first election to elect the two chambers of the Italian Parliament. The *Fronte Popolare* were a coalition between the communist party and the socialist party.

Table 4
Magnitude and timing decomposition.

	(1) Organ donation	(2) Tax compliance	(3) Churches	(4) Civic capital
Panel A. Full Sample				
N. Recent quakes	−0.0005	0.0000	−0.0013	−0.0010
	(0.0007)	(0.0003)	(0.0009)	(0.0007)
	[0.0009]	[0.0005]	[0.0018]	[0.0011]
N. Old quakes	0.0033**	0.0023*	0.0078***	0.0074***
	(0.0020)	(0.0006)	(0.0025)	(0.0021)
	[0.0017]	[0.0012]	[0.0029]	[0.0021]
N. Ancient quakes	0.0044***	−0.0001	0.0089***	0.0074***
	(0.0020)	(0.0006)	(0.0023)	(0.0021)
	[0.0016]	[0.0007]	[0.0027]	[0.0019]
R^2	0.2673	0.4847	0.3247	0.3210
Panel B. High Magnitude				
N. Recent quakes	−0.0025	−0.0028	−0.0047	−0.0056
	(0.0042)	(0.0016)	(0.0032)	(0.0038)
	[0.0044]	[0.0019]	[0.0045]	[0.0045]
N. Old quakes	−0.0034	0.0064***	0.0066	0.0046
	(0.0040)	(0.0014)	(0.0032)	(0.0035)
	[0.0045]	[0.0019]	[0.0041]	[0.0038]
N. Ancient quakes	0.0081**	0.0025*	0.0141***	0.0139***
	(0.0041)	(0.0010)	(0.0034)	(0.0037)
	[0.0039]	[0.0014]	[0.0050]	[0.0041]
R^2	0.2657	0.4857	0.3186	0.3150
Observations	4196	4196	4196	4196
Province FE	✓	✓	✓	✓
Geographic Controls	✓	✓	✓	✓
Historic Controls	✓	✓	✓	✓
Contemporary controls	✓	✓	✓	✓

Notes: This table reports the results of OLS estimates on a cross-section of observations for all the Italian municipalities in the sample that have been hit at least once by an earthquake. The dependent variables are: (1) the number of organ donation associations; (2) the rate of tax compliance of the Italian public TV's fee; (3) the number of churches per square kilometer; and (4) a measure of Civic capital computed as a weighted average of (1)-(3) dependent variables with variance's principal components eigenvectors as weights. In Panel A the independent variables *N. Recent quakes*, *N. Old*, and *N. Ancient quakes* are continuous variables measuring, respectively, (i) all quakes occurred after 1945 until 2011; (ii) all quakes occurred between 1861 and 1945; and (iii) all quakes occurred before 1861. In Panel B the independent variables are the same, but based on a restricted sample of 1754 earthquakes of high magnitude, i.e., earthquakes whose magnitude is higher than 4.63 Mw. Geographic controls include: altitude, ruggedness, surface, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the municipal distance from the closest Ancient Roman road, municipality population in 1100 AD and a dummy equal to one if the municipality was the seat of a bishop by the year 1000 or it borders with one of these towns. Contemporary controls include a dummy for the 25 biggest municipalities in 2011. Robust standard errors in parentheses. Conley's standard errors corrected for spatial dependence with threshold distance of 50km in square brackets. ***, ** and * refer to 10%, 5% and 1% significance, respectively. Statistical significance is indicated employing the Conley's standard errors.

elections), with very similar results.[23] Overall our results suggest that earthquake hazard has an impact on political participation, but not on the political preferences expressed by voting.

6. Robustness checks

In this section we run several falsification tests to ensure that our main results are not just a chance occurrence. As a preliminary check, we present some evidence corroborating the idea that earthquake is not related to other demographic and urban dimensions.

[23] For the 2008 election the left coalition was composed by the *Partito Democratico* and *Italia dei Valori*.

Table 5
Falsification tests.

	(1) Civic capital	(2) Density	(3) Crime	(4) Hospitals	(5) Museums
Quakes within 5 km	0.0353***	23.1747	46.0486	0.0018	−0.0600*
	(0.0048)	(6.6656)	(34.3248)	(0.0011)	(0.0203)
	[0.0087]	[14.2643]	[55.8139]	[0.0021]	[0.0314]
R^2	0.7154	0.8726	0.6881	0.4965	0.5884
Sample: High magnitude					
Observations	7560	7560	7560	7560	7560
Neighbor-pair FEs	✓	✓	✓	✓	✓
Geographic Controls	✓	✓	✓	✓	✓
Historic Controls	✓	✓	✓	✓	✓
Contemporary Controls	✓	✓	✓	✓	✓

Notes: This table reports the results of OLS estimates on a cross-section of observations for those municipalities that form a couple in which a municipality have been hit at least once by an earthquake and its neighbor has not. Each municipality in a pair shares a common pair fixed effect. Geographic controls include: altitude, ruggedness, surface, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the municipal distance from the closest Ancient Roman road, municipality population in 1100 AD and a dummy equal to one if the municipality was the seat of a bishop by the year 1000 or it borders with one of these towns. Contemporary controls include a dummy for the 25 biggest municipalities in 2011. Robust standard errors in parentheses. Conley's standard errors corrected for spatial dependence with threshold distance of 50km in square brackets. ***, ** and * refer to 10%, 5% and 1% significance, respectively. Statistical significance is indicated employing the Conley's standard errors.

6.1. *Falsification tests*

Table 5 replicates the analysis conducted in Table 3 using a different set of dependent variables such as population density (column 2), crime rate (column 3), hospitals and museums per 1000 inhabitants (columns 4 and 5 respectively).

The first falsification test deals with population density. The comparison between Figure A1 in Appendix A.2 and outcomes maps in Fig. 1 may cast doubts that our civic capital measures are merely proxies of municipal population density. As shown in Column 2, however, this is not the case. As expected, earthquake hazard do not cause dense population. In columns (3) to (5) we test whether other variables may proxy for urban environment. In column (3) we use as outcome variable the municipal number of crimes per 1000 inhabitants, while in column (4) we use the number of hospitals per 1000 inhabitants. Estimated coefficients are not statistically significant. Finally in column (5) we use the municipal number of museums per 1000 inhabitants. The estimated coefficient is barely significant, but goes in the opposite direction with respect to column (1). Our earthquake measure is never significant, confirming its irrelevance for other demographic and urban dimensions. This evidence is our first and preliminary step to test the robustness of our results, supporting a causal interpretation of the effect of earthquake hazard on civic capital.

6.2. *Historical migrations*

This section explores the robustness of our results with respect to population migrations. So far we have assumed that historical migrations did not affect prevalent social norms in a municipalities. However, we cannot rule out the possibility that large population inflows (or outflows) might alter the established cultural equilibrium. This problem may be even more severe if migrations are caused by earthquakes hazard or exposure. To address this concern, we replicate the analysis described in Table 3 on subsamples, and controlling for migration flows. Column 1 of Table 6 presents, as reference, the result showed in Column 4, Panel D in Table 3 for *Civic capital*.

First, we investigate whether the differences in the observed levels of civic capital are affected by the Italian North–South economic divide, which caused massive migrations flows from the South to the North during the XX century. To this end, column (2) in Table 6 restricts the sample of municipalities to only those in the South of Italy, while column (3) excludes them.[24] In order to control for historical migration flows at municipal level, the specification in column (4) includes a measure of surname diversity as defined by Buonanno and Vanin (2017): *Entropy*.[25] This variable allows to control for municipal social closure and cumulative past migration inflows. The coefficient associated with *Quakes within 5* km is more than halved, but remains relevant in magnitude and statistical significance. Finally, in column (6) we control for more recent migration flows, i.e. international inflows. We thus add the share of resident foreigners at municipal level. Results are barely affected.

[24] The municipalities of the South are located in the regions of Lazio, Abruzzo, Campania, Molise, Puglia, Basilicata, Calabria, Sicily, and Sardinia.

[25] The Entropy Index in each municipality is calculated as $Entropy = -\sum_{i=1}^{S} p_i log(p_i)$, where S is the total number of surnames in a municipality, and p_i is the municipality's population share with a given surname.

Table 6
Historic migration.

	(1) Civic capital	(2) Civic capital	(3) Civic capital	(4) Civic capital	(5) Civic capital
Quakes within 5 km	0.0353***	0.0272**	0.0354***	0.0122*	0.0365***
	(0.0048)	(0.0067)	(0.0065)	(0.0044)	(0.0050)
	[0.0087]	[0.0121]	[0.0112]	[0.0073]	[0.0090]
Entropy				0.1276***	
				(0.0058)	
				[0.0115]	
Share foreigners					0.3241**
					(0.1041)
					[0.1340]
Sample: High magnitude					
Observations	7560	3084	4476	7558	7371
Neighbor-pair FEs	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓
Sample	All	Only South	No South	All	All

Notes: This table reports the results of OLS estimates on a cross-section of observations for those municipalities that form a couple in which a municipality have been hit at least once by an earthquake and its neighbor has not. Each municipality in a pair shares a common pair fixed effect. Geographic controls include: altitude, ruggedness, surface, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the municipal distance from the closest Ancient Roman road, municipality population in 1100 AD and a dummy equal to one if the municipality was the seat of a bishop by the year 1000 or it borders with one of these towns. Contemporary controls include a dummy for the 25 biggest municipalities in 2011. Robust standard errors in parentheses. Conley's standard errors corrected for spatial dependence with threshold distance of 50km in square brackets. ***, ** and * refer to 10%, 5% and 1% significance, respectively. Statistical significance is indicated employing the Conley's standard errors.

6.3. Selection on information

Working with historical earthquakes comes with problems of selection on information. Before the arrival of modern detection technology, old recorded earthquakes may be just a subsample of the true number of earthquakes. This may cause a selection issue, as we are more likely to have records from denser and richer areas. Figure A3, Panel A and B, seems to confirm this concern. Correlation between *N. Recent quakes* and population density in 2011 is small and, if any, negative. Correlation between *N. Ancient quakes* and population density in 2011 is instead substantial and positive.

To solve this problem of selection we focus on a subset of very strong earthquakes, with magnitude above 5.22 Mw.[26] We argue that detection rate in this subset of strong events should be more homogeneous along time. Figure A2 supports this hypothesis. Compared to Fig. 3, seismic frequency is much more stable over time and does not display any discontinuities in the detection rate. By inspecting Figure A3, in Panels C and D, we confirm that for this small subset of earthquakes the correlation between *N. Ancient quakes* and population density is in line with the one observed for *N. Recent quakes*. Therefore, we replicate the analysis described in Table 3 using the subset of strong earthquakes with magnitude above 5.22 Mw. The results shown in Table 7 confirm that the relation between civic capital and earthquake hazard is not driven by selection on information.

7. Concluding remarks

This paper joins a growing literature exploring the long-run determinants of civic capital. We document that the exposure over centuries to earthquake hazard boosted civic capital accumulation in Italian municipalities, particularly in the pre-industrial period. The hypothesis set forth is that values and beliefs facilitating cooperation emerged in seismic areas as hazard-coping devices, which maximize fitness to external constraints.

Our findings hold when we compare municipalities that have been exposed to earthquake hazard to their neighboring municipalities that have not. A focus on the subsample of treated municipalities (hit at least once by a seismic event) reveals heterogeneous associations between earthquake hazard and civic capital along dimensions such as space, frequency, magnitude, and time. Our results suggest that the causal effect of earthquake hazard on civic capital is primarily driven by severe events that occurred in the past, within 5–10 km of the municipal borders, in line with the intuition that social norms build over a very long time span. These findings are robust to several alternative specifications and to the inclusion of other geographic characteristics, historical controls, the adoption of a restricted sample of powerful seismic events, different reference distances, and a series of falsification tests. We also check that our results are not driven by historical migrations and selection on information. Broadly, our

[26] 5.22 Mw corresponds to the 90th percentile of the distribution of earthquakes by magnitude. So far we have treated as high magnitude events those above 4.63 Mw.

Table 7
Selection on information.

	(1) Civic capital	(2) Civic capital	(3) Civic capital	(4) Civic capital	(5) Civic capital
Quakes within 5 km	0.0923***	0.0912***	0.0524***	0.0496***	0.0474***
	(0.0078)	(0.0068)	(0.0062)	(0.0063)	(0.0064)
	[0.0182]	[0.0158]	[0.0121]	[0.0120]	[0.0122]
R^2	0.0281	0.6271	0.7008	0.7082	0.7210
Sample: Magnitude above 5.22 Mw					
Observations	4871	4871	4871	4867	4867
Neighbor-pair FEs	×	✓	✓	✓	✓
Geographic Controls	×	×	✓	✓	✓
Historic Controls	×	×	×	✓	✓
Specific Controls	×	×	×	×	✓

Notes: This table reports the results of OLS estimates on a cross-section of observations for those municipalities that form a couple in which a municipality have been hit at least once by an earthquake and its neighbor has not. Each municipality in a pair shares a common pair fixed effect. Geographic controls include: altitude, ruggedness, surface, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the municipal distance from the closest Ancient Roman road, municipality population in 1100 AD and a dummy equal to one if the municipality was the seat of a bishop by the year 1000 or it borders with one of these towns. Contemporary controls include a dummy for the 25 biggest municipalities in 2011. Robust standard errors in parentheses. Conley's standard errors corrected for spatial dependence with threshold distance of 50km in square brackets. ***, ** and * refer to 10%, 5% and 1% significance, respectively. Statistical significance is indicated employing the Conley's standard errors.

results indicate that negative aggregate shocks like earthquakes can have a long-lasting positive effect on communities' ability to cooperate. In this respect, our results complement the short-run positive effect of earthquakes on social capital documented in Bai and Li (2021).

Seismicity is, however, but one geographic feature that could have a long-run impact on individual propensity to cooperate — other natural hazards could similarly constitute a trigger for the adoption of cooperative social norms. In turn, these resultant norms may be crucial to efforts to deal with current and future environmental challenges.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.ejpoleco.2023.102367.This section contains supplementary material (i.e., additional estimates and figures) that has not been included in the main body of the paper.

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