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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 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.

Keywords: Civic capital, Cooperation, Social norms, Earthquakes.

JEL Classification: A12, D91, Q54, Z1**.**

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1 Introduction

How do societies cope with aggregate 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 adopt different strategies. Some turn to religion for psychological relief (Van De Wetering, 1982; Sinding Bentzen, 2019; Henrich et al., 2019). In the past, a view of natural disasters as divine punishment reinforced the authority of political figures, who were also religious leaders (Belloc et al., 2016). More generally, efforts to cope with the adversities of life often imply solving social dilemmas, a problem germane to human co-existence (Enke, 2019; Moscona et al., 2020).

In this paper, we aim to shed light on such questions by investigating whether natural disasters like earthquakes induce individuals to cooperate. Specifically, we study whether and in which direction earthquake hazard affects the set of good norms and individual practices often referred to as *civic capital* (Guiso et al., 2011). Indeed, 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 capital than others remains an open debate. Certain scholars believe that this accumulation has an institutional explanation (Putnam, 1993; Guiso et al., 2016), while others point to differences in cultural norms (DellaVigna et al., 2012; Kimbrough and Vostroknutov, 2016; Lowes et al., 2017; Dell et al., 2018; Heldring, 2018), 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. To the best of our knowledge, however, this paper is the first to explore 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 Geophisics and Volcanology, and construct several proxies of natural disaster hazards. This dataset is combined with proxies of civic capital for 8,082 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 (Sinding Bentzen, 2019; Paldam and Paldam, 2017). 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. In particular, a rise of one standard deviation in the earthquake hazard augments civic capital, in our most conservative estimate, by at least 7.4% of a standard deviation. 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 neighbouring municipalities. Our preliminary results remain stable after the inclusion of this possibility.

Our results, could however, be flawed due to the non-random location of earthquakes. That is, unlike the clearly random moment of an earthquake occurrence, its location is not. Indeed, earthquakes 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 selection concerns, we employ several empirical strategies. First, we exploit variation in earthquake hazard across neighbouring municipalities (Acemoglu et al., 2012). Specifically, we add a neighbor-pair fixed effect to our estimating equation, so that the effect of the earthquake hazard is identified by the comparing of municipalities likely to be similar in other economic and geographical characteristics but for their exposure to earthquakes.

Second, 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 assess a subsample of municipalities that experienced 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 alternative definitions of the hit municipalities sample.

Our results 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; Voigtländer and Voth, 2012; Bazzi et al., 2020) 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-run 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), crime (Hombrados, 2020), religiosity (Sinding Bentzen, 2019), GDP per capita (Barone and Mocetti, 2014), delayed transition to self-government (Belloc et al., 2016), and public expenditures (Masiero and Santarossa, 2020).

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; Giuliano and Spilimbergo, 2014; 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 describes the dataset used in our analysis. Section 3 introduces our baseline evidence. Section 4 provides causal evidence that earthquake hazard increases civic capital, while Section 5 presents robustness checks and additional evidence. Section 6 concludes.

2 Data

In what follows, 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 1 presents summary statistics for all 8,092 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.

2.1 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) and Guiso et al. (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 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, 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.[1] 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.[2]

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

[1]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).

[2]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.

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.[3]
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*. Figure 1 presents the geographic distribution across the Italian territory of each measure of civic capital used in the analysis.

2.2 Earthquakes

As they are fairly well distributed across all Italian municipalities, we rely on information about earthquakes to proxy the hazard of natural disasters.[4] 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).[5] The dataset contains information on the 4,584 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 epicentre location. The final dataset comprises 4,354 events.

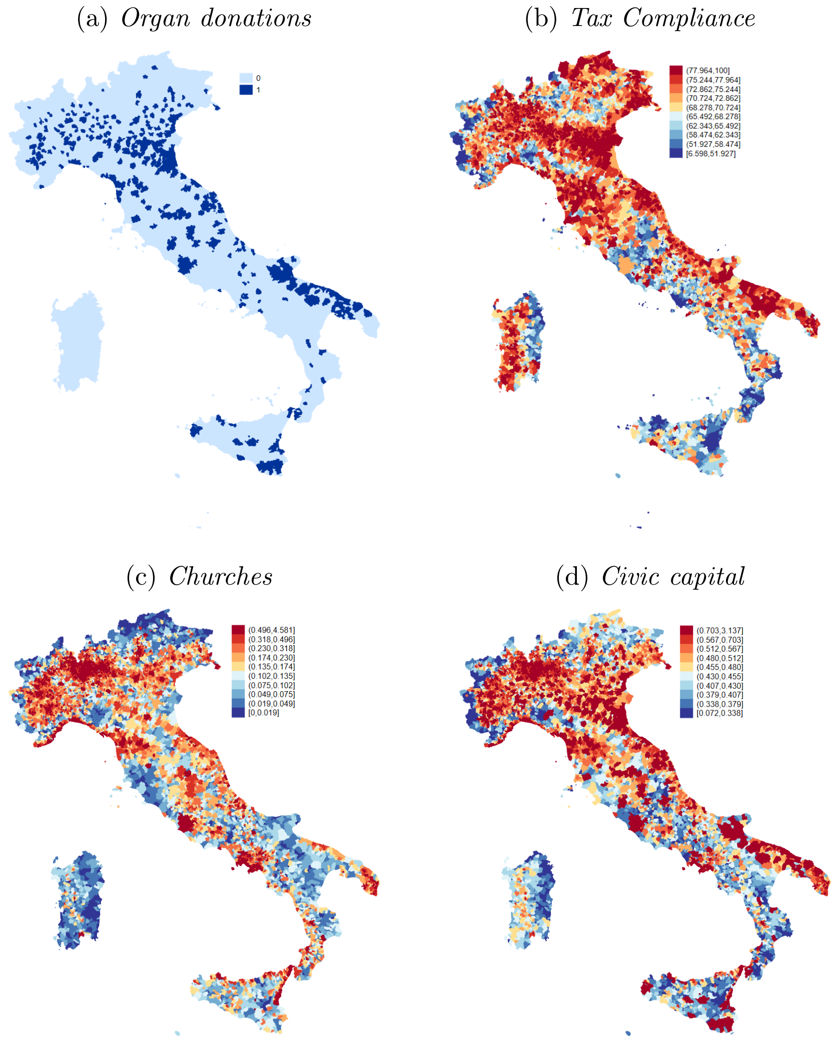
We decompose the information about earthquakes along several dimensions. First, we use the georeferenced earthquake locations to establish whether or not a municipality has ever been hit. To this end, we employ a geographic information system (GIS) to assign a seismic event to each municipality by calculating the distance of an earthquake

[3] 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.

[4] Alternative proxies of natural disasters are comparatively not as informative. Proximity to a volcano would only, for example, 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).

[5] See https://emidius.mi.ingv.it/CPTI15-DBMI15/

Figure 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.

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

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.

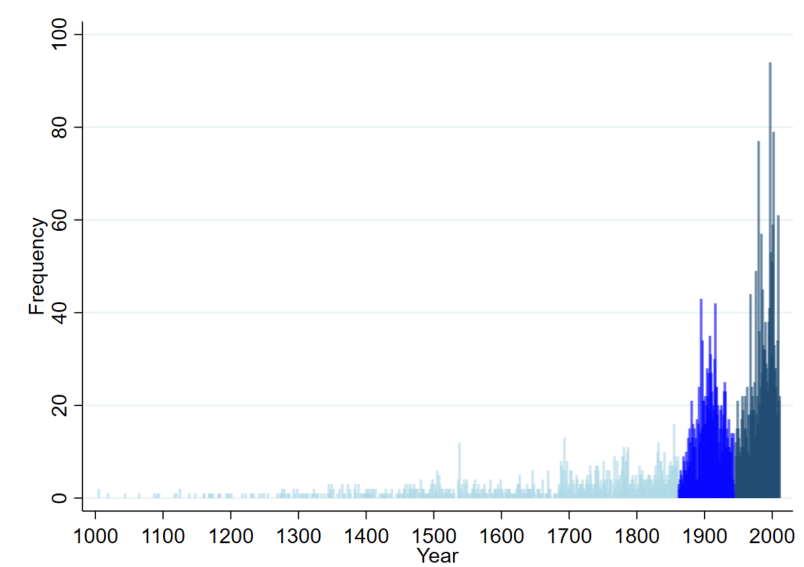
As a second earthquake hazard dimension, we consider the historical timing of seismic events. In particular, we explore whether the latter plays a role in the formation of individual beliefs and shared values, which, in turn, contribute to the accumulation of civic capital. To this end, we separate earthquake occurences 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. Figure 2 displays the time distribution of the 4,354 earthquakes included in the sample, where *Ancient quakes*, *Old quakes*, and *Recent quakes* are reported in light blue, blue, and dark blue, respectively.

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.[6] 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

[6] Available at `https://earthquake.usgs.gov`.

Figure 2: Earthquakes distribution over time



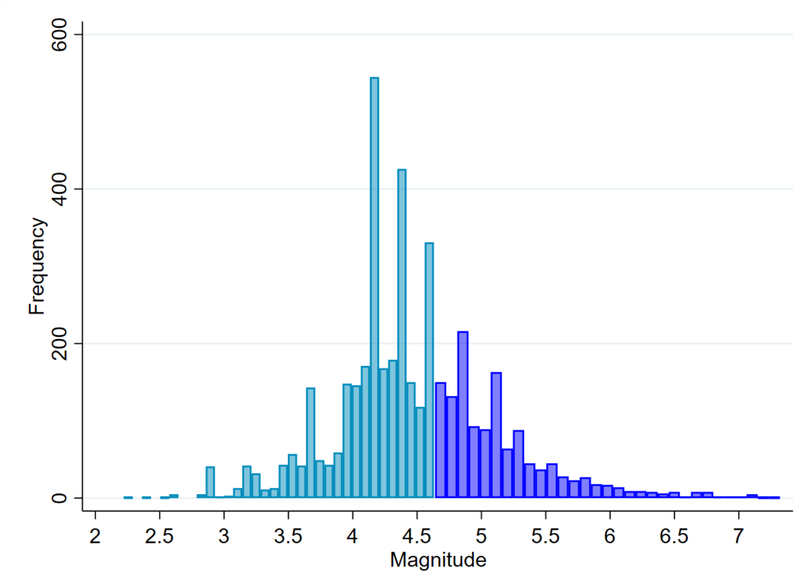
Notes: This figure displays the distribution over time of the earthquakes included in the sample. Each bar represents the total number of earthquakes that occurred in a given year. Events in light-blue occurred before 1861, those in blue between 1861 and 1945, and those in dark-blue after 1945.

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.[7] We also perform sensitivity tests to check that our results are robust to different magnitude thresholds. Figure 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, Figure 4 summarizes the geographic distribution of the main variables used in our analysis, that is municipalities that have been hit by an earthquake within 5km 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.

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

Figure 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) 4.63Mw is reported in light-blue (resp. blue).

2.3 Other historical variables and municipal controls

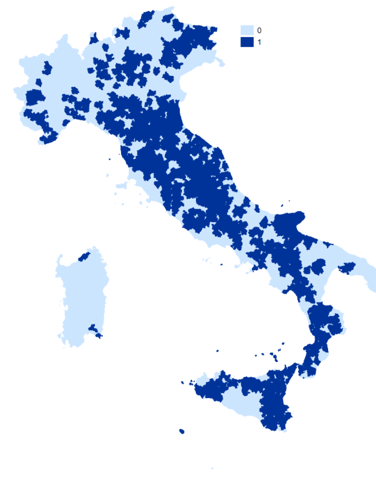
To avoid that our measure of earthquake hazard affects the outcome variables through correlation with omitted municipal climatic, geographic, or even historical features, we also control for various other variables, with a specific focus on those potentially connected with the observed levels of civic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

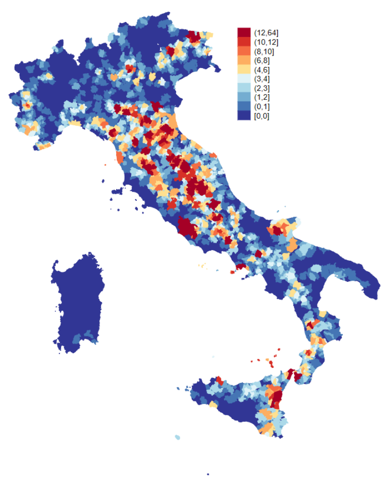
Figure 4: Geographic distribution of Earthquakes

(a) *Quakes within 5km*

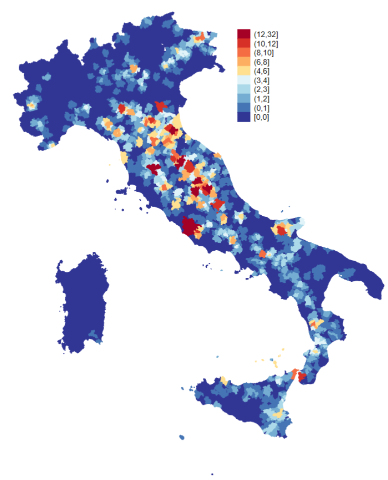
(b) *Quakes within 5km, high magnitude*



(c) *Number of old quakes*



(d) *Number of old quakes, high magnitude*



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.

from the IIASA-FAO Global Agro-Ecological Zones project (*GAEZ*).[8]

Finally, 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

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

and control variables - we focus on the pre-existing municipal topography. Specifically, we include the number of kilometers of major Ancient Roman road within each municipality (*Major Roman Road*), available from the Digital Atlas of Roman and Medieval Civilizations (DARMC), and the estimated total population in 1100 AD (*Population 1100*), taken from Klein Goldewijk et al. (2010).

Appendix A 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.

3 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.

As a preliminary check, we present some evidence corroborating the idea that earthquake hazard affects the level of civic capital in municipalities located close to earthquake epicenters. Table 1 reports the summary statistics for the variables used in the analysis. Specifically, Panel A of Table 1 presents statistics for the municipalities in the sample that have never been hit by an earthquake, while Panel B displays statistics for municipalities that have experienced an earthquake at least once. The t-statistics refer to the differences between the variable means in Panel A and Panel B.

The statistically significant difference between civic capital outcomes suggests that the two groups are systematically different. Yet, with the exception of *Organ donation*, the difference goes in the opposite direction expected, i.e., the average level of civic capital is higher or at least equal in municipalities that have *not* been exposed to earthquake hazard. While this preliminary result could support the hypothesis that a disastrous event leads to individual opportunistic behavior, other factors could equally explain this cross-sectional comparison. We consequently perform a more advanced empirical analysis.

Table 1: Summary statistics

	Panel A: Non-Hit Municipalities					**Panel B: Hit Municipalities**					
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	t
Organ donation	3,819	0.021	0.142	0	1	4,273	0.058	0.234	0	1	-8.597***
Tax compliance	3,813	67.349	10.942	6.598	100	4,270	65.259	11.028	9.873	100	8.538***
Churches × sq. km	3,760	0.226	0.290	0	4.582	4,207	0.212	0.280	0	4.242	2.231**
Civic capital	3,760	0.502	0.196	0.075	3.137	4,207	0.509	0.239	0.072	2.442	-1.312
Sea distance (km)	3,813	81.667	60.584	0	230.344	4,270	59.723	48.775	0	225.028	18.017***
Ruggedness	3,810	209.522	235.264	0.894	1,151.446	4,266	237.065	195.273	0.990	1,035.622	-5.745***
Altitude	3,813	337.068	307.844	0	1,816	4,270	375.335	286.825	0	2,035	-5.784***
Mountainous	3,813	41.778	48.455	0	100	4,270	52.345	47.665	0	100	-9.872***
Land suitability	3,761	5.212	1.331	2	9.25	4,211	5.331	1.097	2	9.077	-4.370***
Major Roman Road	3,760	0.872	2.792	0	37.872	4,207	1.665	5.793	0	266.235	-7.636***
Population 1100	3,810	522.168	1243.763	0	53,202.970	4,265	881.105	5121.778	0	283,997.449	-4.215***
Quakes within 5 km						4,273	1	0	1	1	
Quakes within 5 km, high magnitude						4,273	0.641	0.480	0	1	
N. quakes within 5 km						4,270	4.517	8.749	1	189	
of which:											
N. recent quakes						4,270	40%				
N. old quakes						4,270	31.5%				
N. ancient quakes						4,270	28.5%				

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 within 5 *km*.

3.1 Basic correlation

Table 2 reports the results of OLS estimations of equation (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 kilometers 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 *à la* White (1980), reported in

Table 2: Baseline estimates with Earthquake Dummy

Panel A. Organ donation	(1)	(2)	(3)
Quakes within 5km	0.0412***	0.0338***	0.0321***
	(0.0051)	(0.0054)	(0.0060)
	[0.0058]	[0.0059]	[0.0066]
R^2	0.0890	0.1545	0.1539
Panel B. Tax compliance			
Quakes within 5km	1.3485***	1.2626***	1.3515***
	(0.2191)	(0.2159)	(0.2318)
	[0.4201]	[0.4110]	[0.4135]
R^2	0.4603	0.4731	0.4734
Panel C. Churches			
Quakes within 5km	0.0243**	0.0232**	0.0272**
	(0.0067)	(0.0068)	(0.0070)
	[0.0096]	[0.0098]	[0.0116]
R^2	0.2900	0.2977	0.2980
Panel D. Civic capital			
Quakes within 5km	0.0470***	0.0410***	0.0424***
	(0.0053)	(0.0055)	(0.0059)
	[0.0061]	[0.0065]	[0.0081]
R^2	0.2323	0.2706	0.2708
Observations	7,967	7,951	7,951
Province FE	✓	✓	✓
Geographic Controls	✓	✓	✓
Historic Controls	×	✓	✓
Earthquakes Sample	Full sample	Full sample	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) the number of 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, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the number of kilometers of major Ancient Roman road within each municipality, municipality population in 1100 AD. 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.

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.[9]

In line with our research hypothesis, all estimated coefficients presented in columns (1) and (2) of Table 2 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 and historical control variables. Geographic control variables include terrain ruggedness, the share of mountainous terrain, municipal altitude, an index of land suitability, and distance from the sea. Historic control variables include the number of kilometers of major Ancient Roman road within each municipality, and the estimated total population in the year 1100. It is important to control for these variables because they may be correlated with unobservable factors that affect both economic activities (e.g. trade, mobility, agricultural productivity) and earthquake hazard (e.g. fault lines resulting from Earth crust forces).

Our estimates remain highly significant and the magnitude of the coefficients is barely affected, suggesting that our results are not driven by omitted variables. We observe that a one standard deviation increase in earthquake hazard leads to an increase on average of municipal civic capital by 9.1% of a standard deviation.

While the estimates in columns (1) and (2) use all 4,354 events in our sample, in column (3) we also report the estimates based on a restricted sample of 1,754 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), 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, we estimate a spatial model using a generalized spatial two-stages least squares (GS2SLS) model *à la* Kelejian and Prucha (1998). Table 3 presents the results. In columns (1) to (3), the coefficients are estimated according

[9] 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. 25km, 75km, 100km). We compute Conley standard errors using the acreg command for Stata by Colella et al. (2019).

Table 3: Spatial estimates

Panel A. Organ donation	(1)	(2)	(3)	(4)	(5)	(6)
Quakes within 5km	0.0316***	0.0347***	0.0318***	0.0297***	0.0336***	0.0296***
	(0.0051)	(0.0051)	(0.0051)	(0.0052)	(0.0052)	(0.0051)
λ	0.1200***		0.1166**	0.1482***		0.1494***
	(0.0456)		(0.0463)	(0.0458)		(0.0454)
ρ		0.0258*	0.0164		0.0282**	-0.0400
		(0.0136)	(0.0418)		(0.0135)	(0.0423)
Observations	7,955	7,955	7,955	7,955	7,955	7,955
Panel B. Tax compliance						
Quakes within 5km	0.9589***	1.2478***	1.0002***	1.0317***	1.2654***	1.0673***
	(0.1956)	(0.2491)	(0.2030)	(0.1991)	(0.2552)	(0.2062)
λ	0.4620***		0.4307***	0.4634***		0.4334***
	(0.0288)		(0.0295)	(0.0288)		(0.0294)
ρ		0.5461***	0.0728*		0.5452***	0.0671*
		(0.0109)	(0.0389)		(0.0109)	(0.0390)
Observations	7,955	7,955	7,955	7,955	7,955	7,955
Panel C. Churches						
Quakes within 5km	0.0044	0.0086	0.0065	0.0097	0.0163**	0.0093**
	(0.0059)	(0.0075)	(0.0040)	(0.0060)	(0.0077)	(0.0274)
λ	0.7635***		0.8475***	0.7572***		0.8398***
	(0.0376)		(0.0270)	(0.0379)		(0.0274)
ρ		0.4656***	-0.6516***		0.4651***	-0.6372***
		(0.0123)	(0.0550)		(0.0123)	(0.0555)
Observations	7,951	7,951	7,951	7,951	7,951	7,951
Panel D. Civic capital						
Quakes within 5km	0.0324***	0.0384***	0.0326***	0.0345***	0.0418***	0.0349***
	(0.0051)	(0.0058)	(0.0050)	(0.0052)	(0.0059)	(0.0051)
λ	0.3061***		0.2990***	0.3014***		0.2932***
	(0.0386)		(0.0382)	(0.0392)		(0.0389)
ρ		0.2801***	-0.0446		0.2812***	-0.0298
		(0.0123)	(0.0420)		(0.0123)	(0.0424)
Observations	7,951	7,951	7,951	7,951	7,951	7,951
Province FE	✓	✓	✓	✓	✓	✓
Geographic Controls	✓	✓	✓	✓	✓	✓
Historic Controls	✓	✓	✓	✓	✓	✓
Sample		ALL			High magnitude	

Notes: This Table presents the results of a spatial model estimated by means of the generalised spatial two stage least squares (GS2SLS) estimator of Kelejian and Prucha (1998). Columns 1 to 3 (resp. 4 to 6) reproduce the same specification of columns 2 (resp. column 3) of Table 2. All specifications employ a row-standardised contiguity matrix. Columns 1 and 4 present a spatial error model; columns 2 and 5 present a spatial autoregressive model; columns 3 and 6 present a combination of both a spatial error and a spatial autoregressive lag. ρ is the spatial error term, while λ is the spatial lag. 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, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the number of kilometers of major Ancient Roman road within each municipality, municipality population in 1100 AD. Robust standard errors in parentheses. ***, ** and * refer to 10%, 5% and 1% significance, respectively.

to the same specifications of column (2) in Table 2. In columns (4) to (6), we instead restrict our sample and estimate coefficients according to the specification of column (3) in Table 2. We employ a row-standardized contiguity matrix in all specifications. A spatial error model is implemented in columns (1) and (4), a spatial autoregressive model in columns (2) and (5), and a model that combines the two approaches in columns (3) and (6).

Being the spatial coefficients often significant, earthquake hazard might indeed be relevant for neighboring municipalities, implying that spatial estimates are justified. In this respect, the positive and significant coefficient of the spatial lag is in line with the intuition that spatial spillovers of the earthquake hazard going beyond municipal borders are higher in proximity to the earthquake epicenter.

Allowing our data to follow a spatial structure does not alter our results, independently of the estimation model, with the exception of the *Churches* coefficient that remains significant only for high magnitude events.

4 The Impact of Earthquake Hazard on Civic Capital

4.1 Neighbour-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 neighbouring municipalities. The neighbour-pair fixed effects estimator shares features with a matching and regression discontinuity design, and compares hit municipalities to non-hit neighbouring 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 neighbour-pair fixed effects in the regression model. Second, we can compare neighbouring 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 3.1 (*Quakes within 5 km*) to divide Italian municipalities in hit and non-hit.[10] We then restrict our analysis to the 1,553 hit municipalities (red) that have a non-hit adjacent municipality and these 1,885 non-hit adjacent municipalities (blue). Figure 5 displays hit municipalities and their neighbours. 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.

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

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

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

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 neighbour-pair fixed effects in Table 4. 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. The estimated coefficients of *Quakes within 5 km* are always significant and in line with our theoretical hypotheses. Overall, these results further support the hypothesis that earthquake hazard significantly contributed to the accumulation of municipal civic capital.

5 Robustness checks

In this section, we perform several alternative specifications designed to test the robustness of our estimates. 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 municipal border. Second, we present the results

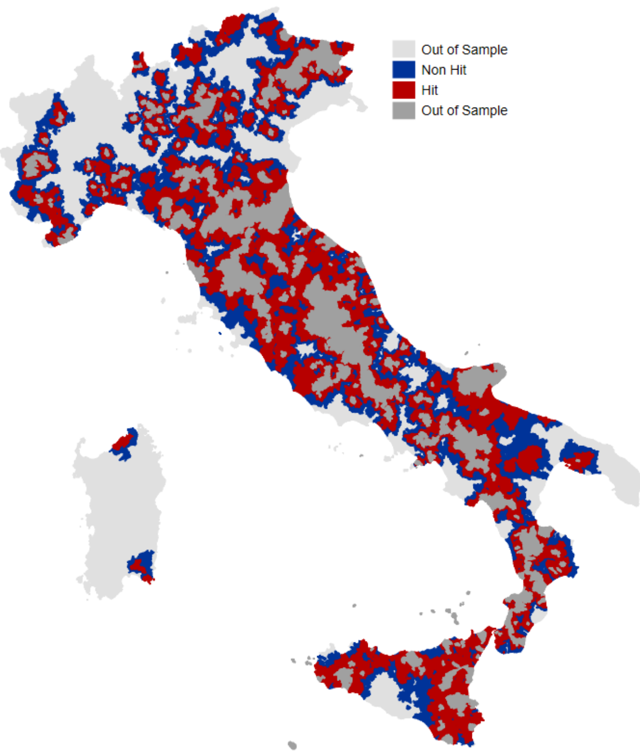
[10] *Quakes within 5 km* is calculated using the restricted sample of high magnitude events, as the inclusion of weak earthquakes could bias the pair definition. The results are not, however, affected by the adoption of the full sample of events.

Table 4: Neighbour-pair Fixed Effect Estimates

Panel A. Organ donation	(1)	(2)	(3)	(4)
Quakes within 5km	0.0896***	0.0897***	0.0914***	0.0783***
	(0.0065)	(0.0062)	(0.0061)	(0.0060)
	[0.0148]	[0.0135]	[0.0136]	[(0.0131]
R^2	0.0248	0.5629	0.5751	0.5997
Panel B. Tax compliance				
Quakes within 5km	1.2975***	1.3204***	1.2700***	1.1489***
	(0.2565)	(0.1730)	(0.1653)	(0.1661)
	[0.3591]	[0.3010]	[0.2835]	[0.2885]
R^2	0.0034	0.7788	0.7948	0.8000
Panel C. Churches				
Quakes within 5km	0.0170**	0.0153**	0.0149**	0.0113*
	(0.0054)	(0.0039)	(0.0038)	(0.0038)
	[0.0074]	[0.0063]	[0.0063]	[0.0062]
R^2	0.0013	0.7486	0.7607	0.7671
Panel D. Civic capital				
Quakes within 5km	0.0750***	0.0744***	0.0750***	0.0638***
	(0.0060)	(0.0052)	(0.0051)	(0.0049)
	[0.0119]	[0.0106]	[0.0107]	[0.0102]
R^2	0.0205	0.6369	0.6563	0.6803
Sample: High magnitude				
Observations	7,573	7,573	7,573	7,565
Neighbour-pair FEs	×	✓	✓	✓
Geographic Controls	×	×	✓	✓
Historic 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 neighbour has not. Each municipality in a pair shares a common pair fixed effect. The dependent variables are (Panel A) the number of 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, distance from the sea coast, the share of mountainous territory, an index of caloric suitability. Historic controls include: the number of kilometers of major Ancient Roman road within each municipality, municipality population in 1100 AD. 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.

Figure 5: Hit Municipalities and their Neighbours



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 1,885 non-hit municipalities that have an adjacent (red) hit municipality (1,553 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.

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.[11]

[11] Appendix A.3 provides additional robustness tests of our estimates for specific subsamples. More precisely, given that the observed levels of civic capital may be correlated with unobservables specific to a few Italian regions, we test that our estimates are also robust to the exclusion of certain areas.

5.1 Distance from the epicenter

We start our robustness checks by exploring whether the distance from an earthquake epicenter matters for the association between civic capital and earthquake hazard. Figure 6 displays the results of the estimations reported in column (3) of Table 2, 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 $d \in \{0, 5, 10, ..., 35\}$ 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 kilometers. 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.

5.2 Treated municipalities

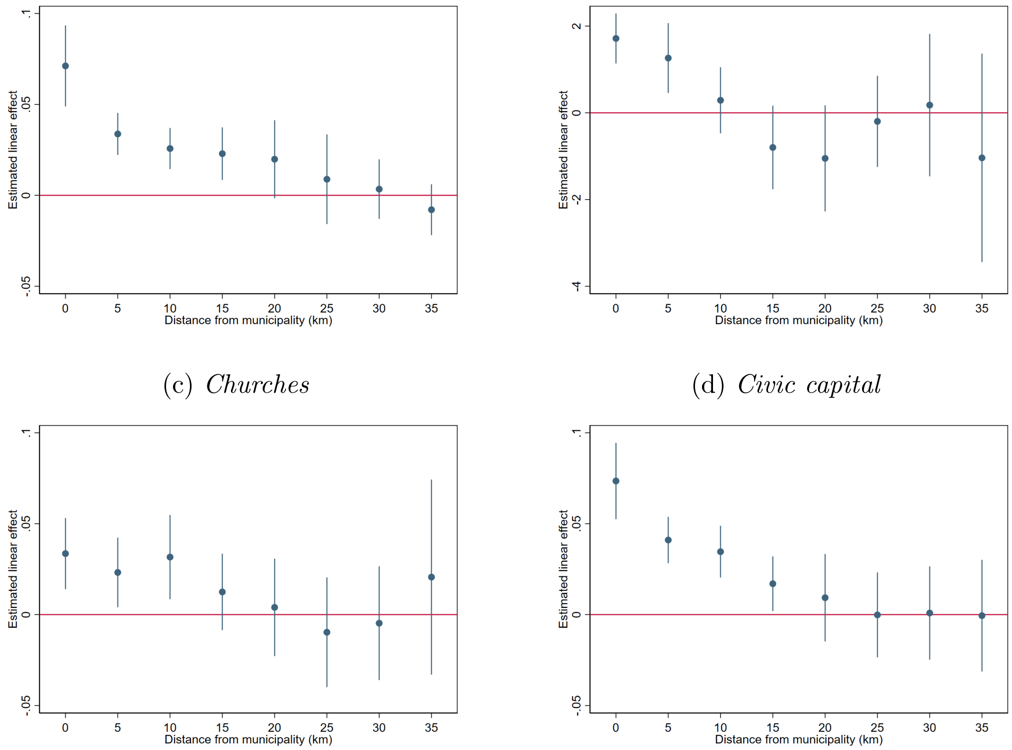
Hit and non-hit municipalities might systematically differ, such that our estimates could suffer a distorsion due to selection bias. To address this concern, we explore the effect of earthquake hazard on hit municipalities only.

Figure 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 $d \in \{0, 5, 10, ..., 35\}$ kilometers. Contrary to those displayed in Figure 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 3.1 and 4.1 are unlikely driven by unobservables that make hit and non-hit municipalities systematically different.

Figure 6: Spatial decomposition of linear prediction

(a) *Organ donation* (b) *Tax compliance*



(c) *Churches* (d) *Civic capital*

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 $d \in \{0, 5, 10, ..., 35\}$ km from a municipality, and zero otherwise, as main independent variables, and the sets of control variables as in Table 2.

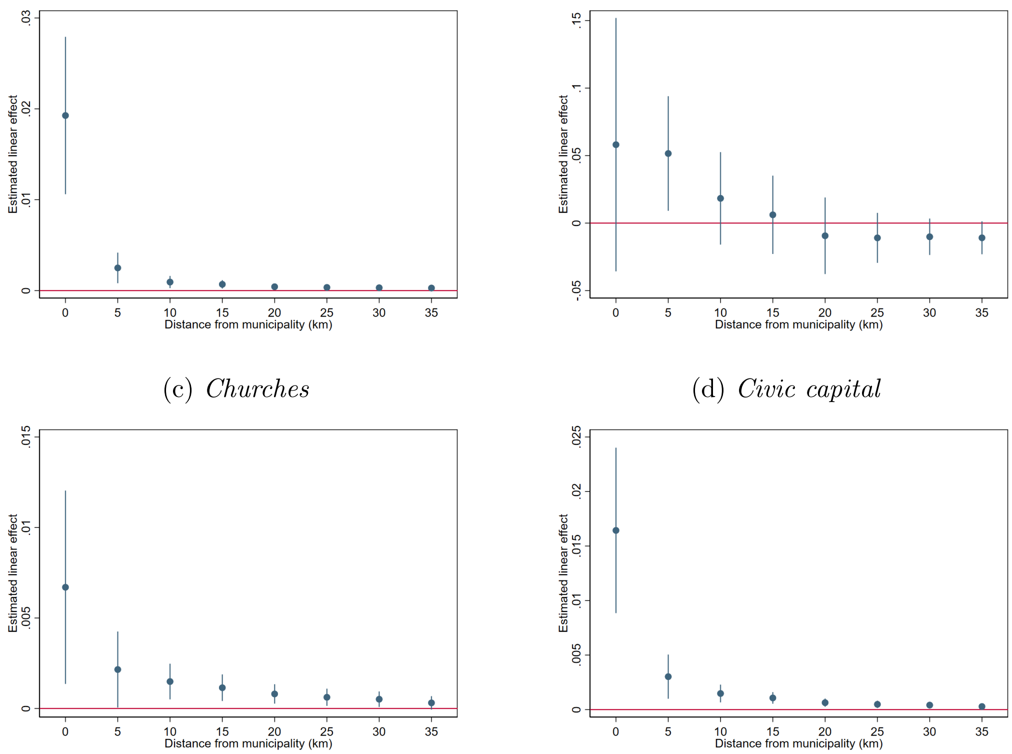
5.2.1 Marginal effect

We further analyze the effect of having experienced more seismic events by looking at the marginal effect of *N. Quakes within* 5-*km*.[12] Figure 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.

An inspection of Figure 8 suggests that the estimated marginal effects gradually ap-

[12] 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 geographic and historical control variables as used in column (2) of Table 2.

Figure 7: Spatial decomposition of linear prediction



(a) *Organ donation* (b) *Tax compliance* (c) *Churches* (d) *Civic capital*

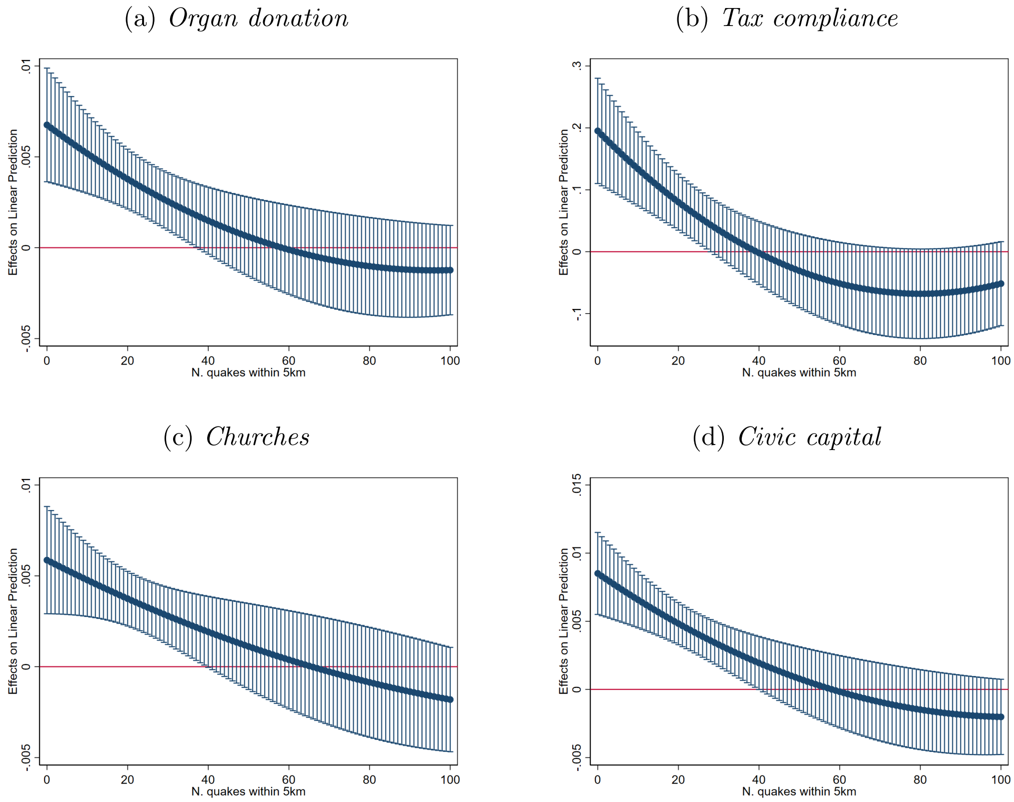
Notes: This figure displays the estimated linear coefficients of OLS regressions with measures of civic capital as dependent variable, the total number of all seismic events located within $d \in \{0, 5, 10, ..., 35\}$ km from a municipal border (*N. Quakes within d-km*), as main independent variables, and the sets of control variables as in Table 2. Coefficients are estimated using subsample of municipalities that have been hit at least once by an earthquake within $d \in \{0, 5, 10, ..., 35\}$ km.

proach 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.

5.2.2 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.

Figure 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 5km from a municipality as main independent variables, and the sets of control variables as in Table 2.

Table 5 reports the results of these estimates, based on the subsample of hit municipalities, where the control variables are the same as in Table 2 and standard errors are computed following the Conley's method (Conley, 1999) with a threshold of 50 km.[13]

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.

[13]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).

Table 5: Magnitude and timing decomposition

	(1) Organ donation	(2) Tax compliance	(3) Churches	(4) Civic capital
Panel A. Time				
N. Recent quakes	0.0005	-0.0140	-0.0028	-0.0012
	(0.0007)	(0.0331)	(0.0010)	(0.0007)
	[0.0010]	[0.0429]	[0.0022]	[0.0012]
N. Old quakes	0.0022	0.2125**	0.0080*	0.0067***
	(0.0019)	(0.0607)	(0.0027)	(0.0021)
	[0.0019]	[0.0995]	[0.0042]	[0.0021]
N. Ancient quakes	0.0097***	0.0332	0.0102***	0.0118***
	(0.0026)	((0.0559)	(0.0026)	(0.0027)
	[0.0024]	[0.0811]	[0.0033]	[0.0027]
R^2	0.1944	0.4881	0.2944	0.2827
Panel B. Magnitude and time				
N. Recent quakes×*High magnitude*	0.0066	-0.1511	-0.0081*	-0.0006
	(0.0046)	(0.1512)	(0.0031)	(0.0039)
	[0.0049]	[0.1785]	[0.0046]	[0.0046]
N. Old quakes×*High magnitude*	-0.0003	0.5921***	0.0045	0.0054
	(0.0043)	(0.1365)	(0.0033)	(0.0037)
	[0.0047]	[0.1931]	[0.0045]	[0.0040]
N. Ancient quakes×*High magnitude*	0.0177***	0.3101**	0.0140***	0.0205***
	(0.0044)	(0.0996)	(0.0034)	(0.0039)
	[0.0044]	[0.1359]	[0.0051]	[0.0046]
R^2	0.1920	0.4895	0.2859	0.2794
Observations	4,199	4,199	4,199	4,199
Province FE	✓	✓	✓	✓
Geographic Controls	✓	✓	✓	✓
Historic 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 variable *High magnitude* is a dichotomous variable equal to one if a municipality has been hit by an earthquake of magnitude greater than 4 on a Richter's scale. In *Panel B* 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 C* we combine independent variables of *Panel A* and *Panel B*. Geographic controls include: altitude, ruggedness, distance from the coast, the share of mountainous municipality territory, an index of caloric suitability. Historic controls include: the number of kilometers of major Ancient Roman road within each municipality, municipality population in 1100 AD. 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.

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 instead interact our measures of earthquake hazard with a dummy variable equal to one if the magnitude of the event is high enough to have caused economic damage (*High Magnitude*), and equal to zero otherwise.

The estimated coefficients in this case are still statistically significant and remain stable in their sign and size for old and ancient seismic events. These findings complement our analysis in showing the potential existence of a causal link between earthquake hazard and civic capital, driven mainly by seismic events of high magnitude that occurred in the past.[14]

6 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 control variables such as geographic characteristics, historical controls, the adoption of a restricted sample of severe events, different reference distances, and alternative definitions of the hit municipalities sample. Broadly, our 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).

[14] Table A2 shows that these findings are robust to the adoption of an alternative definitions of the hit municipalities sample e.g. hit at least twice by an earthquake within 5 km.

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.

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A Appendix

A.1 Variables: Definitions and Sources

Organ donation: Dummy for the presence of an organ donation association (AIDO) in a municipality. *Source*: *Guiso et al. (2016)*

Tax compliance: Municipal percentage of TV license fee compliance, averaged over 2004-2010. *Source*: *RAI Radio Televisione Italiana.*

Churches: Number of Catholic churches per square kilometer in a municipality. *Source*: *Census of the churches of Italian Dioceses.*

Civic capital: First principal components extracted from civic capital variables (*Organ donation, Tax compliance* and *Churches*) at municipal level.

Quakes within 5 km: Dummy equal to one if an earthquake epicenter ever falls within a circle of 5km radius from a municipal border, and zero otherwise. *Source*: Own calculations on data from the *Parametric Catalogue of Italian Earthquakes (2016).*

Quakes within 5 km, high magnitude: *Quakes within 5 km* computed on a reduced sample of strong earthquakes (events above 4.63Mw). *Source*: Own calculations on data from the *Parametric Catalogue of Italian Earthquakes (2016).*

Number of earthquakes within 5 km, Recent: Total number of earthquakes that occurred after 1945 in a municipality. *Source*: Own calculations on data from the *Parametric Catalogue of Italian Earthquakes (2016).*

Number of earthquakes within 5 km, Old: Total number of earthquakes that occurred between 1861 and 1945 in a municipality. *Source*: Own calculations on data from the *Parametric Catalogue of Italian Earthquakes (2016).*

Number of earthquakes within 5 km, Ancient: Total number of earthquakes that occurred before 1861 in a municipality. *Source*: Own calculations on data from the *Parametric Catalogue of Italian Earthquakes (2016).*

Sea distance: Municipal distance (km) from the sea. *Source*: Italian National Institute of Statistics (*ISTAT*)

Ruggedness: Municipal measure of terrain ruggedness constructed from the Global Land

One-km Base Elevation Project (GLOBE). *Source*: *GLOBE*

Altitude: Altitude of the municipal town hall. *Source*: Italian National Institute of Statistics (*ISTAT*)

Mountainous: Municipal share of mountainous territory. *Source*: Italian National Institute of Statistics (*ISTAT*)

Land suitability: Municipal measure of land suitability for rainfed cereals. This measure is constructed using data on crop-specific agro-ecological suitability. *Source*: the IIASA-FAO Global Agro-Ecological Zones project (*GAEZ*).

Major Roman Road: Number of kilometers of major Ancient Roman road within each municipality. *Source*: McCormick et al. (2013) and own elaborations.

Population 1100: Estimated total population in 1100 AD within the boundaries of current-day municipalities. *Source*: Digital Atlas of Roman and Medieval Civilization (DARMC), Center for Geographic Analysis at Harvard University, `http://darmc.harvard.edu`; HYDE-History Database of the Global Environment Klein Goldewijk et al. (2010) and own elaborations.

A.2 Tables

Table A1: Summary statistics

	N	Mean	SD	Min	Max
Organ donation	8,082	0.041	0.197	0	1
Tax compliance	8,083	66.25	11.04	6.59	100
Churches × sq. km	7,967	0.22	0.28	0	4.59
Civic capital	7,967	0.506	0.22	0.0723	3.14
Ruggedness	8,076	224.07	215.49	0.894	1,151.45
Altitude	8,083	357.28	297.52	0	2035
Sea distance (km)	8,083	70.07	55.75	0	230.34
Mountainous	8,083	47.36	48.32	0	100
Land suitability	7,971	5.27	1.21	2	9.25
Major Roman Road	7,967	1.29	4.64	0	266.24
Population 1100	8,065	712.55	3,825.35	0	283,997.4
Quakes within 5 km	8,083	0.53	0.49	0	1
Quakes within 5 km, high magnitude	8,083	0.31	0.464	0	1
N. quakes within 5 km	8,083	2.39	6.75	0	189
N. quakes Recent quakes	8,083	0.95	4.22	0	125
N. quakes Old quakes	8,083	0.75	2.18	0	59
N. quakes Ancient quakes	8,083	0.68	1.99	0	40

Notes: This table reports summary statistics of the variables used in the analysis, for the whole sample of municipalities.

A.3 Further robustness checks

In this section, we conduct further checks to test the robustness of our results. In Table A3 we replicate the baseline results displayed in column (4), *Panel B* of Table 5 (displayed as reference in column (1) of Table A3), by splitting the sample in various ways and adopting a different set of fixed effects.

In particular, column (2) in Table A3 includes local labor system (SLL) fixed effects (rather than province fixed effects).[15] Results are not affected in this new specification. From column (3) to column (7) we test that our results are not driven by few outlier observations. To this end, we re-run our regressions by splitting the sample in various ways. First, we check whether our results are driven by differences in municipality size. Column (3) in A3 restricts the sample of hit municipalities to only those with less than 5000 habitats, while column (4) only those with more than 5000 habitats. We then investigate whether the differences in the observed levels of civic capital are perhaps

[15]The local labor system is a statistical unit that encompasses neighboring municipalities (on average slightly more than 10), across which people usually commute between home and work place.

explained by the Italian North-South economic divide, which many authors attribute to variation in cooperative norms (Banfield, 1958; Bigoni et al., 2016; Guiso et al., 2016). To this end, column (5) in Table A3 restricts the sample of hit municipalities to only those in the South of Italy, while column (6) excludes them.[16] The results are stable across these different sub samples. Finally, in column (7) we exclude the ten largest cities in Italy.[17] This time the results are partially affected, as the coefficient associated with pre-unitarian strong earthquakes shrinks in magnitude. This is possibly due to the fact that centuries ago, in the absence of precise instruments to detect epicentral positions, many seismic events were attributed to large cities by chroniclers. That said, the main result is preserved: *Civic Capital* is positively associated with strong seismic events of the past.

Table A4 checks the robustness of our results to the inclusion of additional control variables. Though many of these controls might be bad controls, we still include them to confirm that our results are not biased by the exclusion of these specific variables. Again, column (1) of Table A4 shows the baseline results displayed in column (4), *Panel B* of Table 5. We include in this baseline specification a different control for each column, from (2) to (6).

The specification for column (2) includes a measure of surname diversity as defined by Buonanno and Vanin (2017): *Entropy*.[18] This variable allows to control for municipal social closure and cumulative past migration inflows. Historical migrations are correlated with past seismic events, and they are also determinants of civic capital. In column (3), we control for a measure of the municipal human capital, as university enrollment is correlated with civic capital and, at the same time, with earthquakes (Cerqua and Di Pietro, 2017). We measure human capital as the share of people with a university degree. In column (4), we control for the municipal income per capita, as this variable could be correlated with recent seismic events and *Tax Compliance*, a component of *Civic Capital*. Finally, in column (5), we control for the surface of the municipality. By construction, municipalities with larger surfaces have an higher probability of being identified as hit by a seismic event and surface is potentially correlated with *Organ*

[16] The municipalities of the South are located in one of the following regions: Abruzzo, Campania, Molise, Puglia, Basilicata, Calabria, Sicily and Sardinia.

[17] Rome, Milan, Napoles, Turin, Palermo, Genoa, Bologna, Florence, Bari and Catania.

[18] 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.

Donation and *Churches*.

As shown in Table A4, strong pre-unification quakes are always positively associated with *Civic Capital*, meaning that our main result is not affected by the inclusion of these confounders.

Table A2: Magnitude and timing decomposition

	(1)	(2)	(3)	(4)
	Organ donation	**Tax compliance**	**Churches**	**Civic capital**
Panel A. Time				
N. Recent quakes	0.0010	-0.0109	-0.0033	-0.0011
	(0.0008)	(0.0338)	(0.0010)	(0.0008)
	[0.0011]	[0.0426]	[0.0023]	[0.0014]
N. Old quakes	0.0023	0.1550*	0.0078*	0.0063***
	(0.0021)	(0.0616)	(0.0028)	(0.0022)
	[0.0019]	[0.0886]	[0.0042]	[0.0021]
N. Ancient quakes	0.0096***	-0.0236	0.0082***	0.0104***
	(0.0027)	(0.0588)	(0.0026)	(0.0028)
	[0.0025]	[0.0833]	[0.0022]	[0.0025]
R^2	0.2115	0.4844	0.3425	0.3132
Panel B. Magnitude and time				
N. Recent quakes×High magnitude	0.0108**	-0.2062	-0.0107**	0.0006
	(0.0049)	(0.1612)	(0.0033)	(0.0040)
	[0.0054]	[0.1845]	[0.0050]	[0.0050]
N. Old quakes×High magnitude	0.0007	0.5186***	0.0025	0.0046
	(0.0048)	(0.1430)	(0.0033)	(0.0040)
	[0.0047]	[0.1895]	[(0.0040]	[0.0038]
N. Ancient quakes×High magnitude	0.0178***	0.2293	0.0119***	0.0190***
	(0.0049)	(0.1055)	(0.0034)	(0.0042)
	[0.0047]	[0.1420]	[0.0044]	[0.0045]
R^2	0.2094	0.4863	0.3335	0.3051
Observations	2,616	2,616	2,616	2,616
Province FE	✓	✓	✓	✓
Geographic Controls	✓	✓	✓	✓
Historic 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 twice 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 variable *High magnitude* is a dichotomous variable equal to one if a municipality has been hit by an earthquake of magnitude greater than 4 on a Richter's scale. In *Panel B* 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 C* we combine independent variables of *Panel A* and *Panel B*. Geographic controls include: altitude, ruggedness, distance from the coast, the share of mountainous municipality territory, an index of caloric suitability. Historic controls include: the number of kilometers of major Ancient Roman road within each municipality, municipality population in 1100 AD. 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.

Table A3: Alternative Samples

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
N. Recent quakes×High magnitude	-0.0006	0.0083	-0.0062***	0.0068	-0.0045	0.0022	-0.0034
	(0.0039)	(0.0050)	(0.0022)	(0.0087)	(0.0050)	(0.0052)	(0.0033)
	[0.0046]	[0.0055]	[0.0026]	[0.0088]	[0.0062]	[0.0055]	[0.0040]
N. Old quakes×High magnitude	0.0054	0.0066	0.0030	0.0128	0.0203**	0.0041	0.0036
	(0.0037)	(0.0043)	(0.0019)	(0.0089)	(0.0084)	(0.0040)	(0.0033)
	[0.0040]	[0.0044]	[0.0022]	[0.0084]	[0.0085]	[0.0046]	[0.0035]
N. Ancient quakes×High magnitude	0.0205***	0.0257***	0.0085***	0.0222***	0.0254***	0.0167***	0.0106**
	(0.0039)	(0.0045)	(0.0028)	(0.0062)	(0.0060)	(0.0047)	(0.0035)
	[0.0046]	[0.0043]	[0.0033]	[0.0070]	[0.0084]	[0.0048]	[0.0043]
Observations	4,199	4,199	2,800	1,399	1,424	2,775	4,190
Baseline Controls	✓	✓	✓	✓	✓	✓	✓
Province FE	✓		✓	✓	✓	✓	✓
local labor system FE		✓					
Sample	All	All	<5000	>5000	Only South	No South	No Large Cities

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 and further sample restrictions. The dependent variable is a measure of Civic capital computed as weighted average of other dependent variables (*Organ Donation*, *Tax Compliance* and *Churches*) with variance's principal components eigenvectors as weights. The independent variables *N. Recent quakes*, *N. Old quakes*, 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 with magnitude greater than 4.5 on a Richter's scale. Geographic controls include: altitude, ruggedness, distance from the coast, the share of mountainous municipality territory, an index of caloric suitability. Historic controls include: the number of kilometers of major Ancient Roman road within each municipality, municipality population in 1100 AD. 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.

Table A4: Additional Controls

	(1)	(2)	(3)	(4)	(5)
N. Recent quakes×High magnitude	-0.0006	-0.0013	-0.0010	-0.0008	-0.0041
	(0.0039)	(0.0036)	(0.0034)	(0.0034)	(0.0037)
	[0.0046]	[0.0043]	[0.0041]	[0.0048]	[0.0044]
N. Old quakes×High magnitude	0.0054	-0.0008	-0.0002	0.0031	0.0043
	(0.0037)	(0.0034)	(0.0034)	(0.0035)	(0.0036)
	[0.0040]	[0.0038]	[0.0035]	[0.0036]	[0.0040]
N. Ancient quakes×High magnitude	0.0205***	0.0128***	0.0110***	0.0167***	0.0177***
	(0.0039)	(0.0034)	(0.0035)	(0.0035)	(0.0038)
	[0.0046]	[0.0039]	[0.0040]	[0.0041]	[0.0046]
Entropy		0.0979***			
		(0.0047)			
		[0.0079]			
Graduate			0.0331***		
			(0.0032)		
			[0.0036]		
Income				0.0340***	
				(0.0028)	
				[0.0039]	
Surface					0.0006***
					(0.0001)
					[0.0002]
Observations	4,199	4,196	4,199	4,199	4,199
Baseline Controls	✓	✓	✓	✓	✓
Province FE	✓	✓	✓	✓	✓
Sample	All	All	All	All	All

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 variable is a measure of Civic capital computed as weighted average of other dependent variables (*Organ Donation*, *Tax Compliance* and *Churches*) with variance's principal components eigenvectors as weights. The independent variables *N. Recent quakes*, *N. Old quakes*, 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 with magnitude greater than 4.5 on a Richter's scale. Geographic controls include: altitude, ruggedness, distance from the coast, the share of mountainous municipality territory, an index of caloric suitability. Historic controls include: the number of kilometers of major Ancient Roman road within each municipality, municipality population in 1100 AD. 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.