The Impact of Earthquakes on Economic Activity: Evidence from Italy[☆]

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Abstract

Although earthquakes are large idiosyncratic shocks for affected regions, little is known of their impact on economic activity. Seismic events are rare, the data is crude - the Richter scale measures the magnitude but says nothing of the associated damages - and counterfactuals are often entirely absent. We suggest an innovative identification strategy to address these issues based on (i) the so-called *'Mercalli scale'* ranks - a geophysical methodology devised to gauge seismic damages - and (ii) a newly compiled dataset following 95 Italian provinces from 1986 to 2011 including 22 seismic episodes. Also, we carry out counterfactuals taking advantage of *ex ante* identical neighboring provinces that only differ *ex post* in terms of damages. Contrary to conventional views, we find that the impact of seismic events on output is negligible (or even positive) including after the most devastating events. A significant and persistent loss in economic activity (a 2.2 percentage points loss in employment) is only detected at the epicentral province of the large 2009 *'Aquilano'* quake.

Keywords: Natural disasters, Output, Employment, Mercalli scale.

JEL: classification Q54, E00, J01.

1. Introduction

To what extent seismic events, which result in capital losses and create disarray in many sectors of the economy, generate deviations of output from trend? Major recent episodes, such as the 2011 *'Tohoku'* earthquake in Japan or the 2009 *'Aquilano'* event in Italy, have revitalized the debate around this question but no consensus has emerged so far in the literature.

Although previous contributions (reviewed below) have relied on vastly different identification strategies, three main empirical challenges have emerged.[1] First, seismic events are large idiosyncratic shocks at the local level but tend to be negligible in aggregated terms, especially in advanced economies. Thus, employing national data results in downwardly estimates of their impact. Second, seismic events are rare and counterfactuals are often entirely absent.[2] Finally, while the moment-magnitude (measured by the Richter scale) is typically employed as a strictly exogenous regressor it is only weakly correlated to the severity and extension of the damages which vary according to a large number of factors, including the deepnes of the epicenter, the type of seismic waves (undulatory vs. sussultory), and the vulnerability of the buildings.

In this paper we contribute to the on-going debate by suggesting an innovative identification strategy based on a newly compiled dataset covering 95 Italian provinces[3] over the period 1986 to 2011 (for a total of 22 seismic events) which provides an ideal setting to address the above empirical issues. While the literature focuses almost exclusively on the effects at the aggregate (national) level we call the attention to the local dimension. The use of provincial data allows to better identify the effects of the quakes that generate damages in a limited number of provinces. Also, because the Richter scale is only weakly correlated to the associated damages [4] (see section 2 for details), we rely on the so-called 'Mercalli scale' ranks, a geophysical methodology devised to classify seismic damages on twelve notches from 'instrumental' (I) to 'catastrophic' (XII). The Mercalli scale, which is based on a narrative desciption of the severity of the damages, is used as a proxy of

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[1]Economic models offer limited guidance beacuse the prediction on the impact on output growth of seismic events strictly depends on the assumptions of the model and the horizon considered (Cavallo et al. [7]).

[2]Few papers have relied on synthetic counterfactuals. Examples include duPont IV and Noy [8] and Barone and Mocetti [3].

[3]Italy is one of the most seismic countries in the world being located in between the Eurasian and the African plate. Statistically, the country experiences a significant earthquake every 4 and a half years. Thanks to a long history of records the National Institute of Geophysics and Vulcanology (INGV) provides all the information on all recorded episodes.

[4]The correlation between the moment magnitude and the severity (and extension) of the damages is zero across provinces affected by the same event because there is only one magnitude for each earthquake measured at the epicenter while the damages vary greatly across provinces.

the capital stock loss suffered at the local level.

In our empirical investigation we consider two alternative dependent variables, the rate of change of provincial output and the employment rate, and run fixed-effect regressions. We identify the impact of seismic events using as a regressor either a strictly exogenous dummy variable (for all provinces reporting at least one municipality above Mercalli III) or the provincial Mercalli ranks (either the maximum or th average of the ranks assigned to the municipalities in each province). Non-linearities in output (and employment) behavior are captured by including the square of the Mercalli rank as a regressor. Possible endogeneity issues of Mercalli ranks are solved by running instrumental variables regressions using the geophysical characteristics of each event (the moment-magnitude and the distance of each province from the epicenter) as strictly exogenous instruments.

Our results, robust to a large set of checks, lead to three main conclusions. First, we provide evidence that seismic events do not display a significant impact on economic activity. This result applies to both, the year of the event and the medium term (five-years horizon). While the point estimates in our regressions exhibit a negative sign, the standard errors are large in all models making the coefficients insignificantly different from zero. The same conclusion is reached when considering the employment rate as dependent variable. Secondly, we obtain the same results when focusing only on the epicentral provinces which typically report the highest and most extended damages. In other words, our evidence holds at "any level of damages", including for the most devastating events. Also, Italian provinces show a peculiar 'insular' aspect as the negative spillover effects from the epicentral province to the neighbors are tested to be negligible.[5] We find the only negative impact on economic activity when considering one of two largest episodes in our dataset, the 2009 *'Aquilano'* event. We identify a negative effect on employment nearly 2.2 percentage points in the year of the earthquake. The negative shock is significant only around the epicenter and only partially reabsorbed the year after. Finally, our results are checked against ideal counterfactuals: contiguous provinces *ex-ante* identical that differ *ex-post* according to the Mercalli rank (graphical evidence largely confirm our results).

Our study contributes to a literature which is still in its infancy. Recent papers have debated regarding the impact of seismic events on output dynamics, but no consensus has emerged so far. Some authors argue that

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[5]For a similar result - altough on a different research question - see Acconcia et al. [1].

earthquakes (and more in general natural disasters) are setbacks for economic growth (Barro and i Martin [4], Raddatz [13]). Along these lines Toya and Skidmore [15] and Noy [11] suggest that most of the cross-section standard deviation of output behavior can be explained by specific observables. Countries with a higher literacy rate, better institutions, higher per capita income, higher degree of openness to trade, and higher levels of government spending are better able to withstand seismic shocks (Noy [11]).[6] In contrast with this strand of the literature, other contributions (Albala-Bertrand [2], Caselli and Malhotra [5], Skidmore and Toya [14], Barone and Mocetti [3]) find mild or even positive effects on growth. Cavallo et al. [7] argue that only extremely large events have a negative effect on output in both, the short and long-run but only if they are followed by political instability while Loayza et al. [10] find that they might activate a creative destruction process even in the short-run.[7]

The rest of the paper is organized as follows. Section 2 explains our identification strategy and introduces the reader to the Mercalli scale. Section 3 presents our empirical models. Section 4 explains the carachteristics of our dataset. Sections 5 shows our baseline results and robustness checks. Finally, section 6 concludes.

2. The Richter and Mercalli Scales: Identifying the Impact of Quakes

In 1935, the American physicist Charles Francis Richter, at the California Institute of Technology, in partnership with Beno Gutenberg developed a methodology to quantify the energy released during an earthquake. Richter and Gutenberg created a base-10 logarithmic scale, which is now known as 'Richter moment-magnitude scale' (or simply 'Richter scale'). The magnitude is based on the 'seismic moment' of the earthquake which is equal to the rigidity of the Earth multiplied by the average amount of slip on the fault and the size of the area that slipped. An earthquake ranked at 6.0 on the Richter scale has a 'shaking amplitude' 10 times higher than one that measures 5.0 and corresponds to a release of energy 31.6 times larger. Nowadays, the magnitude is recorded using an instrument called 'seismograph'.

However, before the invention of seismographs, another scale was developed to categorize earthquakes. In 1783, two Italian architects (Pompeo Schiantarelli and Ignazio Stile) suggested a rudimentary scale to

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[6]In this paper, differences in social capital across provinces are captured by the provincial fixed effect given their persistency over time. Although we control for this factor, the analysis of its direct impact goes beyond the scope of this paper and we reserve to investigate this aspect in more details in future research.

[7]For an excellent surveys of the literature see Cavallo and Noy [6] and Hochrainer [9].

classify the damages generated by the devastating event of that year that stroke in the southern part of the peninsula. The scale underwent several revisions over time and is now known as 'Mercalli scale', named after the Italian volcanologist Giuseppe Mercalli who modified it in 1908. The scale is defined on twelve notches ranging from level I (instrumental) to level XII (catastrophic). The twelve levels are used to categorize the effects of a seismic event on the Earth's surface, human beings, objects of nature, and civil structures. As an example, we report the definition of level VI (strong) of the scale while the remaining levels can be found in AppendixA.

Level VI: *"People - Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily. Fittings - Objects fall from shelves. Pictures fall from walls. Some furniture moved on smooth floors, some unsecured free-standing fireplaces moved. Glassware and crockery broken. Very unstable furniture overturned. Small church and school bells ring. Appliances move on bench or table tops. Filing cabinets or "easy glide" drawers may open (or shut). Structures - Slight damage to buildings type I.[8] Some stucco or cement plaster falls. Windows type I broken.[9] Damage to a few weak domestic chimneys, some may fall. Environment - Trees and bushes shake, or are heard to rustle. Loose material may be dislodged from sloping ground, e.g. existing slides, talus slopes, shingle slides".*

The 'macroseismic intensity' (meaining the destructive power) of an earthquake is not entirely determined by its magnitude. While every earthquake has only one magnitude (recorded at the epicenter), the damages and therefore the Mercalli ranks vary greatly from place to place. In general terms, the negative effects differ across municipalities according to the distance from the epicenter, the degree of urbanization rate, and the structural properties of the buildings. Using the National Institute of Geophysics and Vulcanology ($INGV$) database, figure (1) shows the correlation between the moment-magnitude and the maximum Mercalli rank registered in all recorded episodes in history (3,176 events in total). We also plot the best fit of the data with the 95 percent confidence intervals. As expected, there exists a positive correlation between the two variables.[10] On an average, if the magnitude of the earthquake increases by one level of the Richter scale,

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[8]For the definition of 'building type I' see AppendixA.

[9]For the definition of 'window type I' see AppendixA.

[10]The R^2 of the regression is 0.81.

the severity of the damages measured by the maximum Mercalli rank increases by 1.92 levels of the Mercalli scale. However, the same magnitude is associated to significantly different levels of damages across episodes. For instance, a 6.0 event on the Richter scale generated damages between level VI ('strong') and level X ('intense') of the Mercalli scale which imply radically different damages.

Figure 1: Correlation Mercalli ranks - moment magnitude.
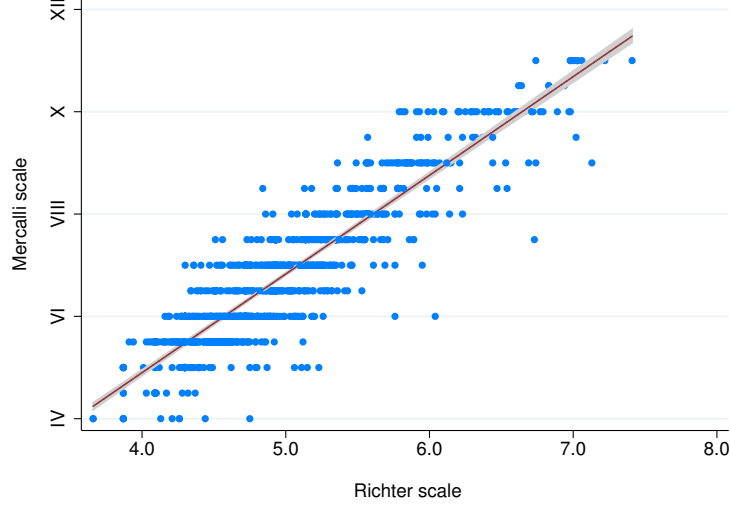
Nowadays following a well-established practice, in the aftermath of an event specialists from the Civil Protection Department (CPD)[11] survey the epicentral region and rank the affected municipalities using the Mercalli scale. As an example, figures (2) and (3) show the maps of two earthquakes in our dataset that received international media coverage: the 1997 'Appennino umbro-marchigiano' event and the 2009 'Aquilano' event.[12] Each dot in the maps represents a municipality (or a sub-municipality[13]) while the colors of the dots reflect the Mercalli ranks (the legend is shown in the figures). In each figure the star locates the epicenter.

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[11]The Department of Civil Protection is a structure of the Prime Minister's Office which coordinates and directs the national service of civil protection. When a national emergency is declared, it coordinates the relief on the entire national territory following natural disasters or catastrophes. In this case, the council of ministers declares the 'state of emergency' by issuing a law by decree and identifies the actions to be undertaken.

[12]The 1997 event received international media coverage because the St. Francis' chapel in Assisi collapsed as a consequence of the quake. The 2009 episode because of the high number of victims (309) and the severity of the damages in one city (L'Aquila).

[13]A 'sub-municipality' (in Italian 'frazione') is a geographically well-defined local which is too small (typically few houndreds or few thousands people) to elect a independent local government. Sub-municipalities are 'affiliated' to the closest municipality.

Figure 2: 'Appennino umbro-marchigiano' (1997) event.
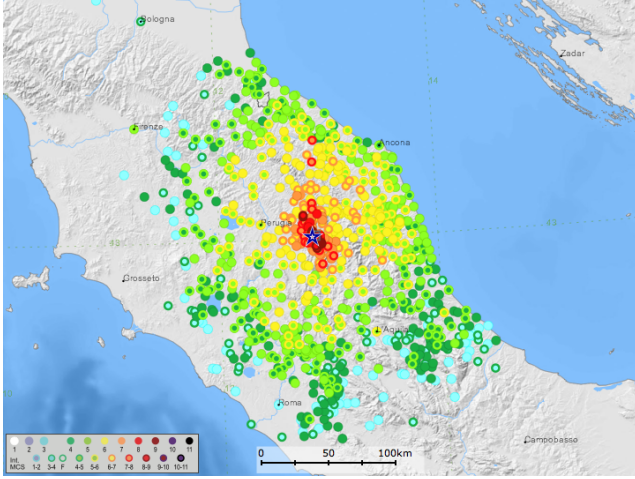
Figure 3: 'Aquilano' (2009) event.
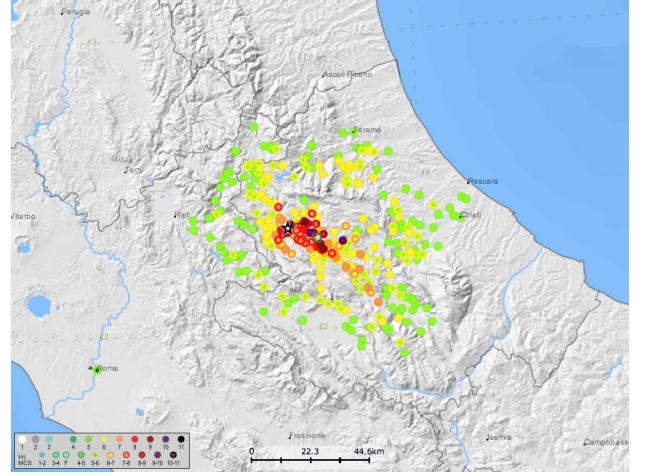
Source: INGV

Source: INGV

The 1997 earthquake affected 869 municipalities (and sub-municipalities) located in 24 provinces in the centern part of the country. Our definition of *'affected municipality'* includes all municipalities above level III of the Mercalli scale (below Mercalli III the quake is not even felt by human beings but only recorded by seismographs). The moment-magnitude of the event was 5.87 on the Richter scale and the maximum Mercalli rank (IX) was registered in the sub-municipality of 'Collecurti' in the province of 'Macerata'. Most of the other highest Mercalli ranks were recorded in municipalities located in the provinces of 'Perugia' and 'Terni' both in the 'Umbria' region. On the other hand, the 2009 *'Aquilano'* event mainly affected municipalities located in the 'Abruzzo' region. The episode generated a moment-magnitude of 6.30 on the Richter scale and the maximum Mercalli rank (IX-X) was registered in the sub-municipalities of 'Castelnuovo' and 'Onna', both in the province of 'L'Aquila'. In total, the event affected 316 locales located in 8 provinces although the great majority were located in one of them ('L'Aquila'). This cross-sectional heterogeneity of damages across provinces (within and between episodes) is at the core of our identification strategy explained in section 3.

3. The Empirical Model

We identify the impact of earthquakes on economic activity by regressing the rate of growth of provincial output on a variable capturing the presence of an earthquake in year t in province p. Seismic events are assumed to be strictly exogenous. In our baseline we specify six models, the first one of which is expressed by

$$Y_{p,t} = \alpha_p + \gamma_t + \beta Earthquake_{p,t} + \boldsymbol{\theta}' \mathbf{X}_{p,t} + \varepsilon_{p,t}, \tag{1}$$

where $Y_{p,t} = \frac{y_{p,t} - y_{p,t-1}}{y_{p,t-1}}$, $y_{p,t}$ is *per capita GDP* in province p in year t, α_p and γ_t are provincial and time fixed effects respectively, $\boldsymbol{\theta}'$ is a vector of coefficients, $\mathbf{X}_{p,t}$ contains a set of controls, and $\varepsilon_{p,t}$ is an idiosyncratic shock. The coefficient of interest is β. The variable $Earthquake_{p,t}$ is a dummy taking the value of '1' if province p reported at least one municipality with a Mercalli rank higher than III in year t. This assumption maximizes the number of positive entries in the dummy since we consider as *'affected'* two levels (III and IV) which are not associated to damages to civil structures. However, our choice ensures that potential negative spillover effects are captured by the model (for instance people might commute from/to neighbooring provinces which we consider as *'affected'* if sufficienlty close to the epicenter). Finally, assuming that the output loss is inversely correlated to the distance from the epicenter (and positively to the Mercalli ranks) from this model we estimate an upper bound of β since we include in the dummy $Earhquake_{p,t}$ provinces reporting lower damages being located farer away from the epicentral region.

As a second approach we replace $Earhquake_{p,t}$ with a dummy ($Epicenter_{p,t}$) that takes the value of '1' only for the epicentral province in each event, the province where the epicenter was located by $INGV$. This second approach is more restrictive and reduces the number of *'affected'* provinces to the number of earthquakes in the dataset (22 in total). From this model we estimate a lower bound of β, our prior being that the output loss is the higher, the closer the province to the epicenter.

Third, in order to account for cross-sectional variations in damages across provinces and seismic events we modify model (1) by replacing the dummy $Earthquake_{p,t}$ with the Mercalli rank ($Mercalli_{p,t}$) of province p in year t. Formally,

$$Y_{p,t} = \alpha_p + \gamma_t + \beta Mercalli_{p,t} + \boldsymbol{\theta}' \mathbf{X}_{p,t} + \zeta_{p,t}, \tag{2}$$

where $\zeta_{p,t}$ is an error term. As a measure of damages we consider the maximum Mercalli rank among all municipalities in the province; in robustness checks we employ the weighted average using the population as a weight and show that our results are fully robust to this assumption[14]. Also, in order to account for possible non-linearities of output behavior with respect to the severity of the damages we add the square of $Mercalli_{p,t}$ as a regressor.

In the last two models we use an instrumental variable approach. An endogeneity bias in our estimates might arise if the Mercalli ranks are correlated to output dynamics - for instance if richer provinces have buildings *ex-ante* less vulnerable to seismic shocks. Our strategy is to run model (2) instrumenting $Mercalli_{p,t}$ using the strictly exogenous geophysical carachteristics of the events. As a first approach we create a municipal-specific indicator ($Intensity_{i,t}$) that proxies the local 'macroseismic intensity' of the event, meaning the distructive power at the micro (municipal) level. This measure interacts two exogenous variables: the moment-magnitude and the inverse of the distance of each municipality from the epicenter. Aggregation at the provincial level is done by taking the unweighted average and use it as a strictly exogenous instrument. Formally, the *Intensity* in province p in year t is defined as

$$Intensity_{p,t} = \frac{1}{N_p} \sum_{i=1}^{N_p} \left(\frac{Magnitude_{i,p,t}}{Distance_{i,p,t}} \right) \tag{3}$$

where N_p is the number of municipalities in province p. *Ceteris paribus,* the higher the magnitude (or the lower the distance from the epicenter), the higher the *'Intensity'* of the event in province p. As a second instrumental variable approach, we use three separate instruments: the magnitude of the event ($Magnitude$), the inverse of the distance[15] from the epicenter ($1/Distance$) and its square $\left(1/Distance^2\right)$. The strict exogeneity of the

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[14]The implicit assumption is that - conditional on Mercalli ranks - the damages are uniformly distributed across types of buildings (especially 'productive' vs. 'non productive'). For privacy issues the details about the damages reported by each affected building are not publicly available. However, partial information is available for the 2009 'Aquilano' event. For this earthquake, the distribution of damages severity across types of buildings is indeed uniform. Furthermore, disruption to economic activity might arise even if productive buildings are not directly affected (roads might be damaged, internet connection might be interrupted, etc..).

[15]The distance is calculated as an unweighted average of the distance of each municipality in the province from the epicenter.

instruments is ensured by the nature of the variables, being determined only by the geophysical caractheristics of the earthquake. Every regression is run twice: the first time allowing for a constant term and time fixed effects; the second time adding all controls (see AppendixB for details on control variables). Finally, to study the dynamic impact of seismic events on economic activity we allow the lags of the main regressor. Model (1) is modified as follows

$$Y_{p,t} = \alpha_p + \gamma_t + \sum_{j=0}^{3} \beta_j Earthquake_{p,t-j} + \boldsymbol{\theta}' \mathbf{X}_{p,t} + \varepsilon_{p,t}. \tag{4}$$

The variable $Earthquake$ is then replaced with $Mercalli$ to consider the heterogeneity of damages across provinces. The regressions are run 6 times, progressively adding lags and controls.

4. Data

Our dataset is a balanced panel of 95 provinces observed over the period 1986-2011, yearly frequency of total 2,470 observations.[16] As a measure of provincial output we use the estimates released by the Italian National Institute of Statistics ($ISTAT$) of the *per capita* value added.[17] As an alternative dependent variable we consider the rate of employment of the population aged 15-64 years released by $ISTAT$ for the period 2004-2011 (760 observations in total). All geophysical data are released by the Italian National Institute of Geophysics and Vulcanology ($INGV$). We consider 22 earthquakes, the first one of which is the 1987 'Reggiano' episode and the last one is the 2009 'Aquilano' event (see table C.5 in AppendixC for details). Geophysical data are provided at the micro-municipal level of disaggregation and they cover the following information: the date of the event, the moment-magnitude (measured by the Richter scale), the geographical coordinates of the epicenter, and the Mercalli ranks of each municipality. Out of 2,470 entries the dummy $Earthquake_{p,t}$ contains 245 positive values. No provinces were affected by two events in the same calendar year. In order to account for the autoregressive path of output, if an earthquake stroke in the last two months of the year we attribute it to the next calendar year. However, our results are unsensitive to this

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[16]Although we have been able to construct the longest time series of provincial GDP growth available at the moment for Italy, the panel structure still contains a large N and a small T. Therefore, typical asymptotic properties of Fixed Effect panel data model estimators (such as Within-the-Group) applies in this case.

[17]For the period 1986-1995 we use the estimates released by the statistical office of the 'Taglicarne Institute' as in Acconcia et al. [1].

choice. A summary of the descriptive statistics is reported in AppendixC. Aggregation of municipal data at the provincial level is performed by taking the unweighted average[18] of all observations within the same province. Finally, all complementary data (control variables) come from $ISTAT$. AppendixB reports the list and the definitions of these variables.

5. Results

The results of our baseline are reported in tables 1 and 2 for output and employment, respectively. The columns in each table reflect the models described in section 3. The last four columns of tables 1 and 2 refer to the instrumental variables approach. For completeness, we show both stages of the $2SLS$ procedure (the first stage is denoted with an $'f'$). As already mentioned, the regressions using output as a dependent variable are run on the entire sample (2,470 observations) while the regressions on employment are run on 760 observations including three seismic events ('Appennino Lucano' (2004), 'Lago di Garda' (2004), and 'Aquilano' (2009)). Table 3 shows the dynamic results; the number of observations decreases to 2,185 as the models progressively allow for lags.

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[18]On average a province is composed by 73 municipalities.

Table 1: Baseline results - Dependent variable: output.

	Fixed Effect								IV			
	(1)	(1c)	(2)	(2c)	(3)	(3c)	(4)	(4c)	(5f)	(5)	(6f)	(6)
Earthquake	-0.055	-0.063										
	(0.159)	(0.157)										
Epicenter			-0.522	-0.510								
			(0.452)	(0.433)								
Mercalli					-0.005	-0.007	-0.100	-0.095		-0.0345		-0.010
					(0.032)	(0.032)	(0.121)	(0.121)		(0.052)		(0.035)
Mercalli^2							0.017	0.015				
							(0.021)	(0.021)				
Intensity									1.990***			
									(0.585)			
Magnitude											0.582***	
											(0.035)	
1/Distance											1.643***	
											(0.189)	
1/Distance^2											-0.192***	
											(0.036)	
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls		YES		YES		YES		YES	YES	YES	YES	YES
Observations	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470
R^2	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.50	0.36	0.95	0.36
Adj R^2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.50	0.33	0.95	0.33
F test of excluded instruments									1765		13638	
Overidentification test, Sargan statistic Chi-sq(2) (P-val)										n.a.		0.7471

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.

Table 2: Baseline results - Dependent variable: employment.

	Fixed Effect								IV			
	(1)	(1c)	(2)	(2c)	(3)	(3c)	(4)	(4c)	(5f)	(5)	(6f)	(6)
Earthquake	-0.282	-0.196										
	(0.223)	(0.211)										
Epicenter			0.266	0.200								
			(0.194)	(0.204)								
Mercalli					-0.071	-0.056	0.097	0.139		-0.066		-0.045
					(0.049)	(0.048)	(0.134)	(0.123)		(0.084)		(0.063)
Mercalli^2							-0.031	-0.036				
							(0.022)	(0.021)				
Intensity									1.942***			
									(0.456)			
Magnitude											0.644***	
											(0.069)	
1/Distance											0.911	
											(0.465)	
1/Distance^2											-0.056	
											(0.109)	
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls		YES		YES		YES		YES	YES	YES	YES	YES
Observations	760	760	760	760	760	760	760	760	760	760	760	760
R^2	0.13	0.13	0.19	0.19	0.13	0.13	0.19	0.19	0.60	0.19	0.96	0.19
Adj R^2	0.12	0.12	0.18	0.18	0.12	0.12	0.18	0.18	0.59	0.06	0.96	0.06
F test of excluded instruments									764		5866	
Overidentification test, Sargan statistic Chi-sq(2) (P-val)										n.a.		0.946

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.

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Table 3: Dynamics.

	Dependent variable: OUTPUT						Dependent variable: EMPLOYMENT					
Earthquake	-0.083	-0.160	-0.272				-0.199	-0.098	-0.073			
	(0.156)	(0.169)	(0.157)				(0.217)	(0.222)	(0.224)			
Earthquake$_{t-1}$	-0.120	-0.115	-0.248				-0.057	0.003	0.039			
	(0.170)	(0.168)	(0.177)				(0.222)	(0.235)	(0.248)			
Earthquake$_{t-2}$		-0.037	-0.021					0.440	0.454			
		(0.189)	(0.188)					(0.240)	(0.248)			
Earthquake$_{t-3}$			-0.093						0.150			
			(0.151)						(0.190)			
Mercalli				-0.011	-0.026	-0.048				-0.056	-0.037	-0.033
				(0.031)	(0.033)	(0.030)				(0.049)	(0.049)	(0.049)
Mercalli$_{t-1}$				-0.017	-0.017	-0.043				0.006	0.019	0.024
				(0.035)	(0.034)	(0.036)				(0.042)	(0.044)	(0.047)
Mercalli$_{t-2}$					-0.014	-0.013					0.086	0.088
					(0.038)	(0.038)					(0.044)	(0.046)
Mercalli$_{t-3}$						-0.031						0.023
						(0.031)						(0.041)
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	2375	2280	2185	2375	2280	2185	2375	2280	2185	2375	2280	2185
R^2	0.36	0.36	0.35	0.36	0.36	0.35	0.19	0.20	0.20	0.19	0.20	0.20
Adj R^2	0.35	0.35	0.34	0.35	0.35	0.34	0.18	0.18	0.18	0.18	0.18	0.18

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.

The main evidence emerging from our baseline is that the coefficient of interest $\left(\hat{\beta}\right)$ is not significant in any model. While the point estimates are virtually all negative, the associated standard errors are high making the coefficients not significant. Only in model 2 of table 2 the coefficient of *Epicenter* is highly significant (with a positive sign); however, when controlling for other observables the significance disappears. Table 3 shows that this result extends to the dynamic impact since no coefficient is significantly different from zero.[19] This result is less surprizing for model 1 because the definition of *'affected province'* includes observations more distant from the epicenter, with a lower *Intensity* and *Mercalli* ranks. However, our main result holds for the epicentral provinces which tipically report more severe and extended damages. Our results also suggest that local economies may actually be 'insular' in their response to earthquakes offsetting the potential negative spillover effects induced by large negative supply shocks at the local level. Furthermore, when the variables *Earthquake* and *Epicenter* are replaced with our measure of damages (*Mercalli*) we obtain the same results of models 1 and 2: the estimated coefficients remain unsignificantly different from zero for both variables, *Mercalli* and *Mercalli*^{2}. In contrast with a common belief, earthquakes do not display a significant impact neither on (local) output growth nor on employment, 'at all levels of damages severity'.

Finally, the instrumental variables regressions confirm the previous evidence. The coefficient of *Mercalli* remains in line to the fixed effects estimates excluding a potential endogeneity bias. The first stages of the $2SLS$ reveal that most of the cross-sectional variation across *Mercalli* ranks is explained by the exogenous carachteristics of the events: the moment *Magnitude* and the *Distance* from the epicenter. Column 5f reports the results by regressing the variable *Mercalli* on the sythetic measure of macroseismic *Intensity* using OLS. The estimated coefficient is highly significant and the positive sign is in line with the prior: *ceteris paribus*, the higher the *Intensity*, the higher the *Mercalli* ranks. On average, increasing the *Intensity* of a province by one unit increases the corresponding *Mercalli* rank by almost two notches. The same evidence emerges from column 6f that reports the results of regressing *Mercalli* on *Magnitude*, the inverse of the *Distance*, and its square. All regressors are significant at one percent level and the R^2 suggests that virtually all variation is explained by the exogenous regressors. The validity of our IV analysis is confirmed[20] by the

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[19]Allowing for more lags in the model does not change our results.

[20]The same evidence applies to robustness checks.

tests reported in the last two lines of each table. In particular, the *first stage F-test* confirms that *Intensity*, *Magnitude*, the inverse of *Distance* and its square are indeed good instruments since the statistics are always above the corresponding critical values.[21] Also, the *Sargan-Hansen test* of over-identifying restrictions[22] is never rejected.[23]

5.1. The Two Major Events

As an additional exercise, we focus on the two events in the dataset that received international media coverage and that we have already described in section 2: the 1997 *'Appennino Umbro-Marchigiano'* earthquake and the 2009 *'Aquilano'*. Our strategy consists of replicating models 1 and 2 of the baseline allowing additional dummies capturing the two episodes. Specifically, we create a dummy variable *Earthquake_Umbria* and *Earthquake_L'Aquila* taking the value of '1' only for the 1997 and the 2009 events respectively and '0' otherwise. Using the same logic, we construct the two variables *Epicenter_Umbria* and *Epicenter_L'Aquila*. Table 4 presents the results of these regressions.

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[21]Stock-Yogo weak ID test critical values for single endogenous regressor are between 22 and 5 according to the maximal IV size.

[22]In our models the joint null hypothesis is that the instruments are valid, i.e., uncorrelated with the error term.

[23]Under the null, the *Sargan-Hansen* test statistic is distributed as chi-squared in the number of (L-K) over-identifying restrictions, were L= instruments, and K=endogenous regressors. A rejection casts doubt on the validity of the instruments.

Table 4: Results - Focus on the two major events.

	Output		Employment	
Earthquake	-0.022		-0.122	
	(0.160)		(0.230)	
Earthquake$_{t-1}$	-0.177		-0.081	
	(0.190)		(0.263)	
Earthquake_Umbria	-0.156			
	(0.459)			
Earthquake_Umbria$_{t-1}$	-0.153			
	(0.448)			
Earthquake_L'Aquila	-1.116		-0.314	
	(1.487)		(0.646)	
Earthquake_L'Aquila$_{t-1}$	1.781		0.102	
	(1.482)		(0.624)	
Epicenter		-0.572		0.259
		(0.422)		(0.193)
Epicenter$_{t-1}$		0.260		0.444
		(0.494)		(0.321)
Epicenter_Umbria		1.583***		
		(0.202)		
Epicenter_Umbria$_{t-1}$		-0.252		
		(0.185)		
Epicenter_L'Aquila		-0.214		-2.240***
		(0.424)		(0.277)
Epicenter_L'Aquila$_{t-1}$		3.709***		1.152***
		(0.482)		(0.314)
Constant	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Observations	2470	2470	760	760
R^2	0.36	0.36	0.19	0.20
Adj R^2	0.35	0.35	0.18	0.18

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level.

Standard errors clustered by province.

Even in this case we do not find a negative impact on output. Rather, output seems to be stimulated

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by the events: 1.5 percent higher growth in the year of the event for the *'Appennino Umbro-Marchigiano'* and 3.7 percent the year after for the *'Aquilano'* episode. In both cases we do not find significant splillover effects from the epicentral provinces to the neighborhood. On the other hand, there is a visible negative effect on the level of employment: 2.2 percentage points negative shock for the *'Aquilano'* quake. The shock, only partially reabsorbed the year after the event, is visible only in the epicentral province (the province of 'L'Aquila').

For these results we provide a graphical intuition/check based on ideal counterfactuals: contiguous provinces *ex-ante* identical that differ *ex-post* in terms of damages.

Figure 4: Output evolution (1986 = 100).	Figure 5: Employment rate.
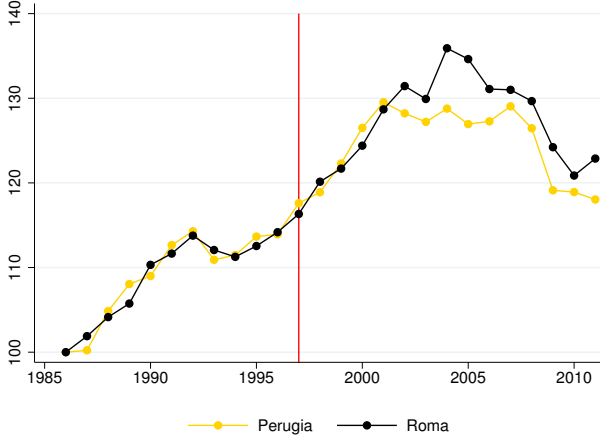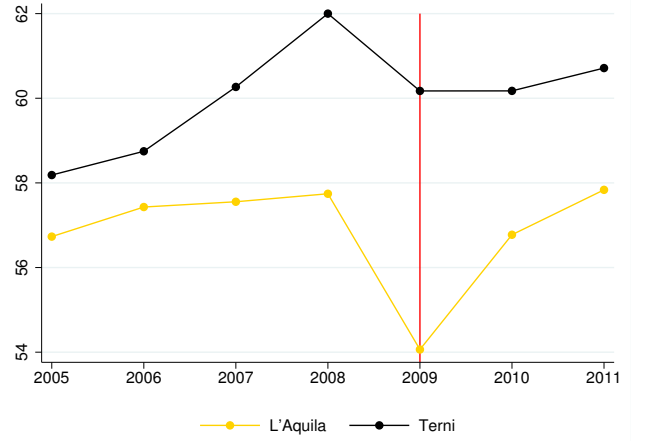
Figure 4 plots the evolution of output for the provinces of 'Perugia' and 'Roma'. The vertical red line indicates the year of the *'Appennino Umbro-Marchigiano'* quake. While the province of 'Perugia' was extensively affected by the earthquake (54 municipalities out of 59[24] involving 96.2 percent of the population had a Mercalli rank equal or above V with a maximum Mercalli rank of VII-VIII) in the province of 'Roma' only marginal damages were registered (8 municipalities, for a total of 1.3 percent of the provincial population

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[24]The five municipalities below level V were: Bastia Umbra, Fratta Todina, Monte Castello di Vibio, Paciano, and Scheggia e Pascelupo.

had a Mercalli rank equal or above V and only two of them were ranked at VI[25]). Visibly, output does not deviate from trend not even the year of the event or the year after. A similar picture can be obtained for the other provinces affected by the 1997 episode.[26] Figure 5 plots the rates of employment for the provinces of 'L'Aquila' and 'Terni' for the 2009 'Aquilano' quake.[27] While the province of L'Aquila was the most affected province by the quake (31 out of 108 municipalities including the city of L'Aquila were ranked above Mercalli V), no municipalities were ranked above Mercalli IV[28] in the province of Teramo. Figure 5 shows that the employment rates in the two provinces displays a high degree of comovement. However, while in 2009 the drop in employment in the province of 'L'Aquila' was 3.6 percentage points, the employment rate dropped only by 1.8 percentage points in the province of 'Terni'.

5.2. Robustness Checks

We verify our baseline results against three alternative specifications. As a first check we eliminate from the sample the events with a *Magnitude* below 5.75 (the mean plus one standard deviation). In this way the variables *Earthquake*, *Epicenter*, *Mercalli*, and *Mercalli*^{2} assume positive values only for the 'big' quakes and zero otherwise. Tables D.7 and D.8 show the results of these regressions for output and employment, respectively. The evidence largely confirms the baseline and the standard errors remain significantly high. However, two differences emerge with respect to the baseline. The point estimate of the coefficients of *Earthquake* and *Epicenter* are higher than the baseline (respectively around six and four times higher) but the high standard errors make us interpret these results with caution (as shown in figure 4 even epicentral provinces of episodes with a high magnitude do not necessarily show a negative deviation of output from trend). Moreover, the coefficients of *Mercalli* and *Mercalli*^{2} (as shown in table D.8) are significant altough

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[25]The list of municipalities in the province of Rome involved in the 1997 event is as follows (Mercalli ranks and population in brackets): Ciciliano (V - 1,105), Mentana (V - 34,326), Montelibretti (V - 4,881) - Nemi (VI - 1,702), Ponzano Romano (V - 1,013), Riano (V - 6,148), Riofreddo (VI - 770), and Roccagiovine (V - 293).

[26]Similar evidence is obtained when constructing reliable counterfactuals for output for the 2009 event.

[27]The province of 'L'Aquila is located in the 'Abruzzo' region while the province of 'Terni' is located in the region of 'Umbria'. The provinces are geographically close to eachother but sufficiently far away (the city of Terni is 96.4 kilometers away from the city of L'Aquila) to prevent people from commuting. Moreover, according to the data provided by the Ministry of Finance, the provinces of L'Aquila and Termi exhibit a very similar economic structure: before the earthquake (average between 2002 and 2008) the two provinces had respectively 6.3 percent and 6.5 percent of total taxpayers declaring a business income (including self employed workers).

[28]Structural damages to buildings start from level VI of the Mercalli scale.

the sign of *Mercalli* is positive. This evidence suggests that employment in provinces reporting more severe damages might even be stimulated presumably as a result of the reconstruction activities which tipically follows the event. According to our estimates, one level increase of the average *Mercalli* rank in an affected province increases employment by around 0.3 percent.

Next, we check whether our baseline results are influenced by the way we aggregate the observations at the municipal level. In our baseline scenario the regressors are constructed by taking the unweighted average of the municipal observations within the same province. In this second check we construct the same regressors as in the baseline but we take the weighted average of municipal observations using the population as a weight. The variables *Earthquake* and *Epicenter* become continuos variables bounded between 0 and 1 representing the share of the population affected by the event and the corresponding share in the 'epicentral province', respectively. On the other hand, the variable *Mercalli* becomes a measure of the damages accounting for their extension. The same weighting scheme applies to the instruments used in models 5 and 6. Tables D.9 and D.10 present the results of this robustness check for output and employment, respectively. Despite the different weighting scheme, the magnitude and significance of all coefficients is comparable to the baseline. Standard errors remain high, the first stages of the instrumental variables regressions remain highly correlated to the damages and no significant impact of earthquakes is found in any model.

Finally, we check whether the baseline evidence is influenced by our classification of *'affected municipality'*. In our baseline we consider as *'affected'* every municipality classified above Mercalli III. Because structural damages to buildings are reported only above the fifth level of the scale in this check we build new regressors starting from this different assumption at the municipal level. Virtually identical results are obtained by weighting the observations using the population as a weight. Tables D.11 and D.12 present the results of this robustness check. Column 2 (and 2c) replicates the baseline since the definition of the dummy *Earthquake* remains the same. All coefficients remain unsignificantly different from zero and in the fixed effects estimates the sign is always positive. Overall, the evidence largely confirm the baseline results.

6. Conclusion

In this paper we quantify the impact of seismic events on local output and employment, relying on a panel of Italian provinces covering 22 seismic episodes. We contribute to the ongoing debate by suggesting an identification strategy based on the so-called 'Mercalli scale' ranks, a narrative description of seismic damages. We show that earthquakes do not have a significant impact neither on output growth nor on employment. Negative effects are found only in one episode (the 2009 event in L'Aquila).

Understanding why output (and employment) does not fall after a quake is beyond the scope of this paper but we briefly discuss three possible explanations. First, the use of annual data might bias downwardly our estimates if output is boosted by higher investment within the same year of the event. However, this scenario seems unplausible especially for big events. Second, the contraction in output and employment might be compensated by policy actions. In a companion paper Porcelli and Trezzi [12] show for a subset of events that most of the output loss is indeed compensated by public reconstruction activities that typically follow the events with output multipliers in the range 1.3 to 2.2. Finally, there might be asymmetric output responses across sectors. Output might be stimulated in some sectors (notably constructions) while contract in others (for instance services). However, disaggregated data across sectors covering the entire considered period are not available. More in general, our results suggest a further need of research in this literature.

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AppendixA. The Mercalli scale - definitions

– **I Instrumental** *People:* Not felt except by a very few people under exceptionally favourable circumstances.

– **II Weak** *People:* Felt by persons at rest, on upper floors or favourably placed.

– **III Slight** *People:* Felt indoors, hanging objects may swing, vibration similar to passing of light trucks,duration may be estimated, may not be recognised as an earthquake.

– **IV Moderate** *People:* Generally noticed indoors but not outside. Light sleepers may be awakened. Vibration may be likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building. *Fittings:* Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock. *Structures:* Walls and frames of buildings, and partitions and suspended ceilings in commercial buildings, may be heard to creak.

– **V Rather Strong** *People:* Generally felt outside, and by almost everyone indoors. Most sleepers awakened. A few people alarmed. *Fittings:* Small unstable objects are displaced or upset. Some glassware and crockery may be broken. Hanging pictures knock against the wall. Open doors may swing. Cupboard doors secured by magnetic catches may open. Pendulum clocks stop, start, or change rate. *Structures:* Some windows Type I cracked. A few earthenware toilet fixtures cracked.

– **VI Strong** *People:* Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily. *Fittings:* Objects fall from shelves. Pictures fall from walls. Some furniture moved on smooth floors, some unsecured free-standing fireplaces moved. Glassware and crockery broken. Very unstable furniture overturned. Small church and school bells ring. Appliances move on bench or table tops. Filing cabinets or "easy glide" drawers may open (or shut). *Structures:* Slight damage to Buildings Type I. Some stucco or cement plaster falls. Windows Type I broken. Damage to a few weak domestic chimneys, some may fall. *Environment:* Trees and bushes shake, or are heard to rustle. Loose material may be dislodged from sloping ground, e.g. existing slides, talus slopes, shingle slides.

– **VII Very Strong** *People:* General alarm. Difficulty experienced in standing. Noticed by motorcar drivers who may stop. *Fittings:* Large bells ring. Furniture moves on smooth floors, may move on carpeted floors. Substantial damage to fragile contents of buildings. *Structures:* Unreinforced stone and brick walls cracked. Buildings Type I cracked with some minor masonry falls. A few instances of damage to Buildings Type II. Unbraced parapets, unbraced brick gables, and architectural ornaments fall. Roofing tiles, especially ridge tiles may be dislodged. Many unreinforced domestic chimneys damaged, often falling from roof-line. Water tanks Type I burst. A few instances of damage to brick veneers and plaster or cement-based linings. Unrestrained water cylinders (water tanks Type II) may move and leak. Some windows Type II cracked. Suspended ceilings damaged. *Environment:* Water made turbid by stirred up mud. Small slides such as falls of sand and gravel banks, and small rock-falls from steep slopes and cuttings. Instances of settlement of unconsolidated or wet, or weak soils. Some fine cracks appear in sloping ground. A few instances of liquefaction (i.e. small water and sand ejections).

– **VIII Destructive** *People:* Alarm may approach panic. Steering of motorcars greatly affected. *Structures:* Buildings Type I heavily damaged, some collapse. Buildings Type II damaged, some with partial collapse. Buildings Type III damaged in some cases. A few instances of damage to Structures Type IV. Monuments and pre-1976 elevated tanks and factory stacks twisted or brought down. Some pre-1965 infill masonry panels damaged. A few post-1980 brick veneers damaged. Decayed timber piles of houses damaged. Houses not secured to foundations may move. Most unreinforced domestic chimneys damaged, some below roof-line, many brought down. *Environment:* Cracks appear on steep slopes and in wet ground. Small to moderate slides in roadside cuttings and unsupported excavations. Small water and sand ejections and localised lateral spreading adjacent to streams, canals, lakes, etc.

– **IX Violent** *Structures:* Many Buildings Type I destroyed. Buildings Type II heavily damaged, some collapse. Buildings Type III damaged, some with partial collapse. Structures Type IV damaged in some cases, some with flexible frames seriously damaged. Damage or permanent distortion to some Structures Type V. Houses not secured to foundations shifted off. Brick veneers fall and expose frames. *Environment:* Cracking of ground conspicuous. Landsliding general on steep slopes. Liquefaction effects

intensified and more widespread, with large lateral spreading and flow sliding adjacent to streams, canals, lakes, etc.

– **X Intense** *Structures:* Most Buildings Type I destroyed. Many Buildings Type II destroyed. Buildings Type III heavily damaged, some collapse. Structures Type IV damaged, some with partial collapse. Structures Type V moderately damaged, but few partial collapses. A few instances of damage to Structures Type VI. Some well-built timber buildings moderately damaged (excluding damage from falling chimneys). *Environment:* Landsliding very widespread in susceptible terrain, with very large rock masses displaced on steep slopes. Landslide dams may be formed. Liquefaction effects widespread and severe.

– **XI Extreme** *Structures:* Most Buildings Type II destroyed. Many Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.

– **XII Catastrophic** *Structures:* Most Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.

Construction types. *Buildings Type I:* Buildings with low standard of workmanship, poor mortar, or constructed of weak materials like mud brick or rammed earth. Soft storey structures (e.g. shops) made of masonry, weak reinforced concrete or composite materials (e.g. some walls timber, some brick) not well tied together. Masonry buildings otherwise conforming to buildings Types I to III, but also having heavy unreinforced masonry towers. (Buildings constructed entirely of timber must be of extremely low quality to be Type I.). *Buildings Type II:* Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the corners, but neither designed nor reinforced to resist lateral forces. Such buildings not having heavy unreinforced masonry towers. *Buildings Type III:* Reinforced masonry or concrete buildings of good workmanship and with sound mortar, but not formally designed to resist earthquake forces. *Structures Type IV:* Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special collapse or damage limiting measures taken (mid-1930s to c. 1970

for concrete and to c. 1980 for other materials). *Structures Type V:* Buildings and bridges, designed and built to normal use standards, i.e. no special damage limiting measures taken, other than code requirements, dating from since c. 1970 for concrete and c. 1980 for other materials. *Structures Type VI:* Structures, dating from c. 1980, with well-defined foundation behaviour, which have been specially designed for minimal damage, e.g. seismically isolated emergency facilities, some structures with dangerous or high contents, or new generation low damage structures. **Windows.** *Type I:* Large display windows, especially shop windows. *Type II:* Ordinary sash or casement windows. **Water tanks.** *Type I:* External, stand mounted, corrugated iron tanks. *Type II:* Domestic hot-water cylinders unrestrained except by supply and delivery pipes.

AppendixB. List and definition of control variables

Population: total number of residents at December, 31th of each year. *Source: ISTAT.* **Population65:** share of population older than 65 years old resident at December, 31th of each year. *Source: ISTAT.* **Population85:** share of population older than 85 years old resident at December, 31th of each year. *Source: ISTAT.* **Index of young dipendency:** ratio between number of people younger than 14 years old and people in working age (14-65 years old) at December, 31th of each year. *Source: ISTAT.* **Index of senior dipendency:** ratio between number of people older than 65 years old and people in working age (14-65 years old) at December, 31th of each year. *Source: ISTAT.*

AppendixC. Summary statistics

Table C.5: List and geopysical carachteristics of earthquakes.

Name	Month	Year	Magnitude	Mercalli Max	Dimension	Provinces affected
Aquilano	April	2009	6.30	IX-X	316	8
Lago di Garda	November	2004	5.06	VII-VIII	176	23
Appennino Lucano	September	2004	4.49	VI	156	6
Subappennino Dauno	November	2002	5.72	VII	645	14
Molise	October	2002	5.74	VIII-IX	51	2
Carnia	February	2002	4.74	VI	173	4
Merano	July	2001	4.84	VI-VII	663	11
Appennino Calabro-Lucano	September	1998	5.03	VII	37	3
Appennino umbro-marchigiano	September	1997	5.87	IX	869	24
Correggio	October	1996	5.18	VII	135	24
Cosentino	April	1996	4.83	VII	123	2
Irpinia	April	1996	4.94	VI	557	11
Lunigiana	October	1995	5.10	VII	341	13
Gargano	September	1995	5.12	VI	145	10
Sicilia sud-orientale	December	1990	5.37	VII-VIII	304	10
Potentino	May	1990	5.95	VII	1374	24
Canavese	February	1990	4.81	VI	201	3
Pasubio	September	1989	5.10	VI-VII	770	21
Costa calabra	April	1988	5.19	VI-VII	272	5
Reggiano	March	1988	4.73	VI-VII	160	5
Appennino lucano	January	1988	5.33	VII	112	1
Reggiano	May	1987	5.09	VI	802	18

Note: 'Dimension' refers to the number of 'affected municipalities' (ranked above Mercalli III).

Table C.6: Summary Statistics.

Variable	Observations	Mean	Std. Dev.	Min	Max
Dependent variable					
GDP growth	2,470	0.969	2.867	-14.946	12.603
Employment rate	760	58.141	9.290	36.333	72.423
Earthquake-specific					
Mercalli	245	3.423	1.348	0.136	6.309
Magnitude	245	5.255	0.508	4.411	6.300
Intensity	245	0.953	1.192	0.189	13.746
Distance	245	0.999	0.575	0.158	3.066
Earthquake-specific (weighted averages)					
Mercalli	245	3.576	1.324	0.331	6.498
Magnitude	245	5.261	0.509	4.433	6.300
Intensity	245	0.904	1.029	0.188	9.463
Distance	245	1.018	0.591	0.133	3.071
Controls					
Population	2,470	607,000	643,508	87,842	4,211,864
Population65	2,470	18.725	3.710	8.42	27.94
Population85	2,470	2.036	0.775	0.47	4.53
Index young dip.	2,470	21.780	4.665	13.6	39.9
Index old dip.	2,470	28.173	6.126	12.86	45.94

Note: for the geophysical carachteristics the statistics are computed only for the non-null values.

AppendixD. Robustness checks - tables

Table D.7: Events with high magnitude -Dependent variable: output.

	Fixed Effect								IV			
	(1)	(1c)	(2)	(2c)	(3)	(3c)	(4)	(4c)	(5f)	(5)	(6f)	(6)
Earthquake	-0.322	-0.322										
	(0.355)	(0.357)										
Epicenter												
Mercalli					-0.052	-0.053	-0.285	-0.274		-0.148		-0.064
					(0.062)	(0.062)	(0.259)	(0.261)		(0.090)		(0.121)
Mercalli^2							0.038	0.036				
							(0.039)	(0.039)				
Intensity									2.971***			
									(0.4821)			
Magnitude											0.582***	
											(0.035)	
1/Distance											1.643***	
											(0.189)	
1/Distance^2											-0.192***	
											(0.036)	
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls		YES		YES		YES		YES	YES	YES	YES	YES
Observations	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470
R^2	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.61	0.36	0.95	0.36
Adj R^2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.61	0.33	0.95	0.33
F test of excluded instruments									2446		314	
Overidentification test, Sargan statistic Chi-sq(2) (P-val)										n.a.		0.8233

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.

Table D.8: Events with high magnitude - Dependent variable: employment.

| | Fixed Effect | | | | | | | | IV | | | |
	(1)	(1c)	(2)	(2c)	(3)	(3c)	(4)	(4c)	(5f)	(5)	(6f)	(6)
Earthquake	-0.494	-0.445										
	(0.518)	(0.533)										
Epicenter			-0.095	0.093								
			(0.151)	(0.224)								
Mercalli					-0.114	-0.105	0.365*	0.370*		-0.066		-0.128
					(0.086)	(0.091)	(0.165)	(0.166)		(0.137)		(0.172)
Mercalli^2							-0.073***	-0.072***				
							(0.015)	(0.015)				
Intensity									1.875*			
									(0.744)			
Magnitude											0.644***	
											(0.069)	
1/Distance											0.911	
											(0.465)	
1/Distance^2											-0.056	
											(0.109)	
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls		YES		YES		YES		YES	YES	YES	YES	YES
Observations	760	760	760	760	760	760	760	760	760	760	760	760
R^2	0.13	0.13	0.19	0.19	0.13	0.14	0.19	0.20	0.60	0.19	0.96	0.19
Adj R^2	0.12	0.12	0.18	0.18	0.12	0.13	0.18	0.18	0.60	0.06	0.96	0.06
F test of excluded instruments									848		120	
Overidentification test, Sargan statistic Chi-sq(2) (P-val)										n.a.		0.9669

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.

Table D.9: Weighted variables - Dependent variable: output.

	Fixed Effect								IV			
	(1)	(1c)	(2)	(2c)	(3)	(3c)	(4)	(4c)	(5f)	(5)	(6f)	(6)
Earthquake	-0.103	-0.111										
	(0.169)	(0.168)										
Epicenter			-0.489	-0.484								
			(0.479)	(0.463)								
Mercalli					-0.025	-0.028	-0.052	-0.048		-0.079		-0.016
					(0.039)	(0.039)	(0.189)	(0.188)		(0.062)		(0.046)
Mercalli^2							-0.006	0.004				
							(0.040)	(0.040)				
Intensity									1.836***			
									(0.311)			
Magnitude											0.568***	
											(0.036)	
1/Distance											1.577***	
											(0.167)	
1/Distance^2											-0.167***	
											(0.024)	
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls		YES		YES		YES		YES	YES	YES	YES	YES
Observations	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470
R^2	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.57	0.36	0.93	0.36
Adj R^2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.56	0.33	0.92	0.33
F test of excluded instruments									2401		6571	
Overidentification test, Sargan statistic Chi-sq(2) (P-val)										n.a.		0.9448

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.

Table D.10: Weighted variables - Dependent variable: employment.

	Fixed Effect								IV			
	(1)	(1c)	(2)	(2c)	(3)	(3c)	(4)	(4c)	(5f)	(5)	(6f)	(6)
Earthquake	-0.412	-0.240										
	(0.225)	(0.229)										
Epicenter			0.252	0.243								
			(0.207)	(0.203)								
Mercalli					-0.102	-0.062	0.189	0.180		-0.039		-0.053
					(0.052)	(0.055)	(0.298)	(0.302)		(0.122)		(0.076)
Mercalli^2							-0.064	-0.053				
							(0.064)	(0.068)				
Intensity									1.227*			
									(0.514)			
Magnitude											0.624***	
											(0.086)	
1/Distance											1.071	
											(0.580)	
1/Distance^2											-0.084	
											(0.156)	
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls		YES		YES		YES		YES	YES	YES	YES	YES
Observations	760	760	760	760	760	760	760	760	760	760	760	760
R^2	0.13	0.19	0.13	0.19	0.13	0.19	0.14	0.19	0.47	0.19	0.96	0.19
Adj R^2	0.13	0.18	0.12	0.18	0.13	0.18	0.12	0.18	0.46	0.06	0.96	0.06
F test of excluded instruments									376		3561	
Overidentification test, Sargan statistic Chi-sq(2) (P-val)										n.a.		0.9909

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.

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Table D.11: Excluding Mercalli lower than V - Dependent variable: output.

	Fixed Effect								IV			
	(1)	(1c)	(2)	(2c)	(3)	(3c)	(4)	(4c)	(5f)	(5)	(6f)	(6)
Earthquake	0.009	-0.006										
	(0.223)	(0.221)										
Epicenter			-0.522	-0.510								
			(0.452)	(0.433)								
Mercalli					0.005	0.002	-0.135	-0.127		-0.051		-0.005
					(0.038)	(0.037)	(0.212)	(0.208)		(0.059)		(0.048)
Mercalli^2							0.023	0.021				
							(0.034)	(0.033)				
Intensity									1.763***			
									(0.490)			
Magnitude											-0.012	
											(0.062)	
1/Distance											2.851***	
											(0.341)	
1/Distance^2											-0.297***	
											(0.062)	
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls		YES		YES		YES		YES	YES	YES	YES	YES
Observations	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470	2470
R^2	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.46	0.36	0.66	0.36
Adj R^2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.46	0.33	0.65	0.33
F test of excluded instruments									1719		1340	
Overidentification test, Sargan statistic Chi-sq(2) (P-val)										n.a.		0.7186

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.

Table D.12: Excluding Mercalli lower than V - Dependent variable: employment.

	Fixed Effect								IV			
	(1)	(1c)	(2)	(2c)	(3)	(3c)	(4)	(4c)	(5f)	(5)	(6f)	(6)
Earthquake	-0.411	-0.419										
	(0.399)	(0.365)										
Epicenter			0.266	0.200								
			(0.194)	(0.204)								
Mercalli					-0.083	-0.082	0.239	0.197		-0.078		-0.055
					(0.067)	(0.063)	(0.227)	(0.205)		(0.099)		(0.095)
Mercalli^2							-0.051	-0.044				
							(0.029)	(0.029)				
Intensity									1.651***			
									(0.328)			
Magnitude											-0.016	
											(0.158)	
1/Distance											1.396	
											(1.133)	
1/Distance^2											0.088	
											(0.247)	
Constant	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Controls		YES		YES		YES		YES	YES	YES	YES	YES
Observations	760	760	760	760	760	760	760	760	760	760	760	760
R^2	0.13	0.13	0.19	0.19	0.13	0.13	0.19	0.19	0.62	0.19	0.67	0.19
Adj R^2	0.12	0.12	0.18	0.18	0.12	0.12	0.18	0.18	0.62	0.06	0.67	0.06
F test of excluded instruments									1009		419	
Overidentification test, Sargan statistic Chi-sq(2) (P-val)										n.a.		0.8663

*** indicates significance at 0.1% level, ** at 1% level and * at 5% level. Standard errors clustered by province.