Received: 10 December 2018 | Revised: 7 June 2019 | Accepted: 11 July 2019

DOI: 10.1111/jors.12462

ORIGINAL ARTICLE

JOURNAL OF REGIONAL SCIENCE WILEY

Earthquakes, grants, and public expenditure: How municipalities respond to natural disasters

Giuliano Masiero[1,2] | Michael Santarossa[3]

[1]Department of Management, Information and Production Engineering, University of Bergamo, Bergamo, Italy

[2]Institute of Economics (IdEP), Università della Svizzera italiana (USI), Lugano, Switzerland

[3]Department of Economics and Management, University of Pavia, Pavia, Italy

Correspondence
Giuliano Masiero, Department of Management, Information and Production Engineering, University of Bergamo, via Pasubio 7b, Dalmine (BG), 24044 Bergamo, Italy.
Email: giuliano.masiero@unibg.it

Abstract

We analyze the response of municipalities to the occurrence of natural disasters in terms of spending behavior, use of upper-tier transfers and recovery, using balance sheet data of about 8,000 Italian municipalities for the period 2000–2015, and the universe of earthquakes events. We find evidence of increasing expenditure for about 12 years after the shocks, with asymmetric responses between earthquake-related and unconditional grants, and heterogeneous flypaper effects across the country. While in northern municipalities expenditure tends to regress to pre-earthquake levels, southern municipalities stick to higher expenditure levels when grants drop. This evidence is coupled with a faster recovery of private income and housing prices in northern municipalities.

KEYWORDS

economic growth, flypaper effect, intergovernmental transfers, local expenditure, matching grants, natural disasters

JEL CLASSIFICATION

H52; H72; R50

1 | INTRODUCTION

Natural disasters have several implications on affected economies and society. Infrastructures get damaged and need to be repaired, people get injured or die, economic activities are unable to operate, and inequalities may worsen (Bui, Dungey, Nguyen, & Pham, 2014; Kahn, 2005; Strömberg, 2007). Whether it is because of legal rules, solidarity or to raise the consensus of the electorate, public authorities commonly intervene by means of higher spending levels and transfers of financial resources from the central government to disaster areas

(Barone & Mocetti, 2014; Noy & Nualsri, 2011).[1] It has been noted that expenditure on postdisaster relief is generally less efficient and effective than expenditure on prevention (Healy & Malhotra, 2009; Skoufias, 2003). However, governments prefer to deal with disaster relief measures since the electorate is more likely to perceive (or misperceive) the benefits and, therefore, to provide political consensus (Cavallo & Noy, 2010). Despite the involvement of local authorities and their role as the main channel of interaction between citizens and regional/central governments to face natural disasters, there is lacking evidence on the response of local public expenditure in terms of resources use and timing, and the subsequent impact on recovery (Bevan & Cook, 2015).

This paper investigates the response of local government expenditure to natural disasters exploiting detailed data on expenditure and transfers from the universe of Italian municipalities for a 16-year period (2000–2015), and a large historic data set of seismic events since 1000 AD. To this aim, we estimate expenditure variation following earthquake occurrence using panel data regression models on the universe of municipalities as well as on a matching sample, focusing on immediate and medium-run effects of earthquakes. Further, since disasters are particularly good examples of exogenous shocks to economies, we exploit the variability in transfers received for earthquake damage recovery to identify a possible source of inefficiency in postdisaster interventions, that is, the overreaction to transfers from upper tiers to lower government levels that can offset the growth of income—the so-called *flypaper effect* (see, e.g., Gennari & Messina, 2014; Hamilton, 1983). Due to their essential matching-grants nature and their duration, the response to earthquake-specific transfers may be more pronounced as compared to other sources of transfers, implying both an income and a substitution effect (Bailey & Connolly, 1998) and leading to persistent path dependency of local governments' expenditure over time. We apply a matching procedure to disentangle different types of grants and explore differences in the response to earthquake-specific and general grants. Then, we investigate the asymmetric responses to increasing and decreasing grants and between northern and southern municipalities in terms of resources allocation and recovery.

We find that an earthquake increases local government expenditure immediately after the shock by about 2%, following an inverse U-shaped trend, which persists for about 11–12 years since the disaster. This increase is mainly driven by transfers of financial resources from the central and regional governments. Further, we find evidence of flypaper effects with asymmetric responses to matching (earthquake-related) and unmatching grants and to increasing and decreasing grants. Finally, we testify differences in the response of northern and southern municipalities, suggesting that the less efficient use of earthquake-specific grants by southern municipalities leads to poor economic outcomes.

Despite the size of public resources employed in the recovery from losses of natural disasters and the long-lasting effort of public authorities, only a few studies analyze the response of public expenditure to natural disasters and its impact. Melecky and Raddatz (2011) investigate the effect of natural disasters on fiscal sustainability using data on a number of high and middle-income countries for the period 1975–2008, and show that public expenditure grows to allow for recovery. Noy and Nualsri (2011) find that governments of developed countries tend to support more disaster areas by means of transfers of financial resources, while governments in developing countries are less committed or even contract the resources transferred to disaster areas. Other studies focus on the impact of natural disasters on economic growth and show that economic gains are context related (e.g., Barone & Mocetti, 2014; Cavallo, Galiani, Noy, & Pantano, 2013; Skidmore & Toya, 2002). Damages from natural disasters may provide the opportunity to reorganize economic activities in affected areas and, therefore, to foster urban development (Xu & Wang, 2019). However, areas with better predisaster socioeconomic conditions are more capable to exploit this opportunity as compared to areas with worse predisaster conditions (Bondonio & Greenbaum, 2018). Looking at two Italian regions struck by severe earthquakes in 1976 and 1980, Barone and Mocetti (2014) show that in the medium run (i.e., the first 5 years after the disaster) transfers from the central government allow to entirely cover the losses, but remarkable differences are observed between the two regions in

[1]In Italy—a country frequently struck by earthquakes—the central government allocated almost 100 billion euro at 2014 prices to fund disaster relief just for the five largest seismic events that occurred between 1968 and 2002 (Di Giacomo, 2014).

terms of ability to recover. Hornbeck and Keniston (2017) find that Boston city reconstruction after the 1872 fire is an example of successful recovery with beneficial effects on land and house values and urban growth, while Horwich (2000) finds that the port of Kobe in Japan, struck by a severe earthquake in 1995, was able to recover from damages within 1 year, but economic growth slowed down because part of economic activities moved to other port cities.[2]

Our analysis contributes to a deeper knowledge of the effects of postdisaster public spending, which helps policy-makers to design more effective and efficient relief measures. Usually, natural disasters affect a limited area of a country and, even if an event is not catastrophic, damages may be remarkable at local level. Hence, observing the consequences of these events from a within-country perspective may improve the precision of the analysis. The large majority of studies mentioned above focus at country level and analyze the economic impact of the largest natural disasters, neglecting smaller but harmful disasters. Clearly, cross-country studies can only exploit a limited number of rare and big events, which may undermine the validity of the results. Our approach allows to capture the effects of relatively small events since we exploit data for the universe of Italian municipalities and a unique historic data set of all seismic events. Italy is an ideal setting because the country was struck by several hundreds of earthquakes over the last decades, out of which only 19 were large catastrophic events.[3] Moreover, local governments are responsible for housing services, urban road maintenance, economic development, social protection, and education, all aspects that are likely affected by catastrophes.

The rest of the paper is structured as follows. Section 2 describes the institutional setting and how public authorities respond to natural disasters. Section 3 presents the data and some descriptive evidence on the incidence of earthquakes and changes in public expenditure. Section 4 defines the empirical strategy and Section 5.1 presents the main results on expenditure behavior and provides some robustness checks. In Section 5.24.2, we extend the analysis to investigate the role of transfers, and in Section 5.3, we explore differences in the response to earthquakes, that is, asymmetric responses to increasing and decreasing grants and heterogeneous flypaper effects across municipalities. Finally, in Section 5.4, we further explore differences in the response of northern and southern local governments in terms of timing and spending composition, and the effects on economic growth. Section 6 concludes.

2 | INSTITUTIONAL AND SEISMIC BACKGROUND IN ITALY

2.1 | Exposure to earthquake risk

Italy is a country with a high frequency of earthquakes. The country is almost continuously exposed to minor earthquakes and several large events occurred both recently and in the past. However, it is necessary to distinguish the physical strength of an earthquake from the damages it causes. A very strong earthquake that occurs in a not populated area without infrastructures may not cause any damage, while a mild earthquake that strikes a town with weak infrastructures may cause human losses and large damages. The 2017 earthquake of Ischia was a relatively weak earthquake (moment magnitude 4), but very destructive because of poor building standards present in the area. This distinction is of relevance also because Italy is rich in cultural heritage, which is difficult to protect against natural disasters.

Figure 1 illustrates the frequency of earthquakes with intensity equal or bigger than 5 at municipality level for the period 1985–2015. Intensity 5 is the lowest level at which damages occur (see Section 3.2 on earthquake measurement for details). The map highlights that earthquakes occur across the entire country. One-third of municipalities were struck at least once by a seismic event over the considered period and almost half of them in

[2]Note that Horwich (2000) uses information on 19 months after the disaster. This does not exclude that the area could have recovered from economic damages in the long run, as found by Davis and Weinstein (2002) after city bombings in Japan during World War II.

[3]Our elaboration on data provided by the Center for Research on the Epidemiology of Disasters (Guha-Sapir, Below, & Hoyois, 2017).

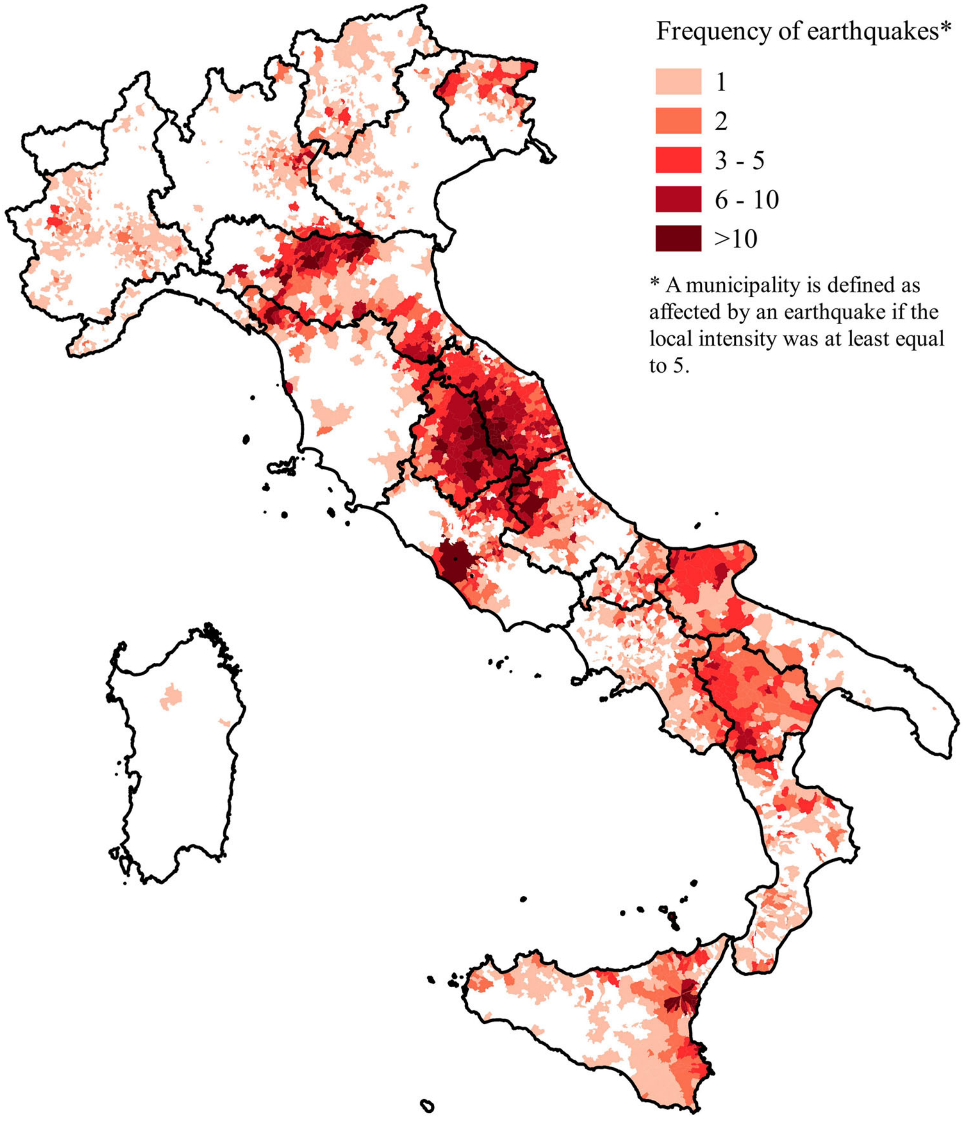

FIGURE 1 Frequency of earthquakes by municipality (1985–2015). The map represents the frequency of earthquakes with intensity ≥ 5 by municipality for a 31-year period (1985–2015). The darker the color, the higher the frequency. White areas represent municipalities that did not face any earthquake with intensity ≥ 5 over the period. *Source*: Our elaboration on data from the DBMI15 database of the Institute for Geophysics and Volcanology (Locati et al., 2016). The shape map of the 2016 administrative borders is provided by the Italian Institute for Statistics. [Color figure can beviewed at wileyonlinelibrary.com]

the period 2000–2015. The areas most frequently affected are the regions Emilia-Romagna in the north, Umbria, Marche, and the municipality Rome in the center, and Abruzzo, Basilicata, Northern Puglia, and Eastern Sicily in the south.

The exposure to earthquake risk leads to the classification of municipalities into seismic zones. In 2004, the Italian Institute for Geophysics and Volcanology (INGV), a unit of the Civil Protection with the task to increase the knowledge on the Earth system and its phenomena and to monitor seismic and volcanic events, analyzed the probability to face large earthquakes based on the movement speed of the ground and defined, accordingly, four seismic zones. A more detailed classification with subcategories was realized in 2015. This classification is of interest for the central government because it allows to address policies to the most exposed areas. One of these policies defines building standards that must be fulfilled in high-risk seismic zones. Moreover, the central government allocates funds for infrastructure maintenance to prevent disaster damages based on the classification.

2.2 | Administrative organization and response to natural disasters

Italy is a decentralized country where the public administration consists of four levels: the central government, the region, the province, and the municipality. The main task of regions is the provision of services in the health-care sector. Provinces are responsible for the maintenance of nonurban roads, environmental protection and secondary education. Municipal governments are required to offer a number of services, among which the most relevant are local transports, urban road maintenance, waste disposal, housing, social protection, and primary education.

Since the early 1990s, the administrative organization has changed. The Law 142/1990 started a decentralization process of powers from the central government toward local authorities with the attempt to increase the autonomy of local governments. This implied a change in the composition of funding sources. Since 1992, an increasing share of local government revenues derived from the withholding of tax revenues, mainly from property taxes and surcharges on income taxes, and from the revenues generated by local service provision. However, decisions on local tax rates are constrained by national regulation that limits the extent to which local governments can leverage on taxation. The central government reallocates resources among local governments with the purpose to grant equal access to essential services across the country. In 2002, a fund for equalization was established. The resources are distributed to local governments, both directly and through regional governments, so that governments with insufficient own resources are able to provide the necessary services to the population.[4] To grant equal access to basic services across the country, the central government funds up to 70% of the expenditure reported in the balance sheet of the year before.[5] The other services need to be funded with own resources.

In 2015, local governments spent 83 billion euro, which is 10% of total public expenditure in Italy. Transfers of financial resources from the central and regional governments and from other public institutions account for 14% of current revenues. These transfers are mainly unconditional. Current transfers represent on average 70% of total transfers and they are generally non-earmarked transfers, while the remaining share represents capital transfers, which are generally distributed for specific projects, such as the construction of infrastructures. The remaining 86% of local government revenues is composed of own resources. Almost half of own resources are produced by local taxation (Italian Institute for Statistics, 2017).

The response of public authorities to natural disasters consists of two phases. Immediate aid is provided to meet short-run needs, such as the provision of food and medicals, the preparation of emergency camps, and the inspection and evaluation of damages to infrastructures. Later on, effort is put in the recovery from losses and in the prevention of future disasters. Generally, funds for recovery from damages are matching grants, that is, they meet spending requirements for specific projects proposed by local public authorities.

Although central authorities are not obliged to intervene in the case of natural disasters, usually they offer immediate support through the Civil Protection Department.[6] Moreover, the law empowers the central government to claim the state of emergency and define its duration and the involved area (Art. 5 of Law 225/

[4]The benchmark adopted by the central government is the average revenue of municipalities of a given demographic class. Decree Law 267/2000 (Testo unico delle leggi sull'ordinamento degli enti locali) classified municipalities into 12 demographic classes based on the size of the resident population and defined regulation accordingly, because population size determines differences in needs.

[5]Since 2009, services provided by local governments are divided into basic services and other services. Basic services are general administration, local police, education, local transport, social protection, and local services. Local services are housing, Civil Protection, waste disposal, water services, and services for environmental protection.

[6]The Civil Protection Department, which is administered by the Presidency of the Council of Ministers, guides the prevention, response, forecast, and risk monitoring activities related to both natural and man-made disasters through central and local units across the country.

1992). This claim has two main implications. First, the central government can recur to decrees to face the situation notwithstanding the current regulation. In this way, public authorities can intervene immediately without the need to recur to legislative procedures, which could impede a prompt and proper response to the catastrophe. The second implication is that the state of emergency allows to transfer financial resources from the fund of the Civil Protection to the affected areas. However, this procedure can have a drawback in terms of timing. The central government can claim the state of emergency only upon request from regional governments through the Civil Protection. Commonly, regional governments decide whether to ask for the state of emergency based on the size of damages. They delegate the collection of information from the citizens to local governments, a procedure that could delay effective intervention.[7]

For medium and long-run support to disaster areas, the central government needs to follow ordinary legislative procedures. Based on the size of damages resulting from inspections, financial resources for the reconstruction of capital and the recovery of economic activities are allocated by means of decree laws. A final tool at government disposal is the yearly financial law, which allows to allocate additional resources to the areas affected by catastrophic events.

3 | DATA AND DESCRIPTIVE EVIDENCE

3.1 | Data

In this study, we use three main data sets: (a) local government balance sheet data, (b) data on earthquake occurrence, and (c) data on municipality characteristics. Data on local government expenditure are available for 7,997 Italian municipalities observed for 16 years (2000–2015).[8] The panel data set is obtained from the Italian Ministry of the Interior and contains detailed information on expenditure as well as revenues of local governments for each year.[9] Our measure of expenditure (revenues) is the sum of current and capital expenditures (revenues) registered in the competence and residual accounts in each year.[10]

We gathered data on earthquakes from two databases available from INGV that collects information on earthquake occurrence between 1000 and 2014.[11] The first database is the parametric catalog of earthquakes CPTI15 (Rovida, Locati, Camassi, Lolli, & Gasperini, 2016) that includes detailed information on each earthquake (e.g., magnitude, maximum intensity, coordinates of the epicenter). The second database is the macroseismic database DBMI15 (Locati et al., 2016), which reports local earthquake-intensity measures. The selection criteria for the inclusion of an earthquake in the databases are either a maximum intensity equal to or greater than 5 on the Mercalli scale, or a moment magnitude equal to or greater than 4.[12] Although data on earthquakes for 2015 are not available, their impact is likely negligible since INGV stated that fewer earthquakes occurred than in 2014 and only 18 shocks had a magnitude equal to or above 4, no one bigger than 5.

[7] In 2002 and 2003, further regulation was introduced to reduce the time of response and the exposure to seismic risk. In case of extreme events that threaten lives of individuals, the government can assign special powers to a delegate even before claiming the state of emergency (Art. 3 of Law 245/2002). Also, an additional fund, managed directly by the premiership, was established to transfer resources to regional and local governments for both prevention and disaster relief (Art. 32-bis of Decree Law 269/2003).

[8] A small number of municipalities merged over this period. Therefore, to construct a homogeneous panel over the entire period, we aggregate the data of merged municipalities in the years before the merger. We replicate the 2016 municipality structure because some data are available only for that level of aggregation.

[9] Actually, we have data for the period 1990–2015 but differences in the statistics before 1998 and the lack of data on household income in 1998 and 1999 advise not to use those data before 2000.

[10] The competence account registers expenditures and revenues related to cash flows, while the residual account registers transactions for which the cash flow has not occurred yet.

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

[12] The intensity is measured on the Mercalli scale and quantifies the observed effects of an earthquake on a scale from 1 to 12. The moment magnitude is a logarithmic scale that measures the energy released by an earthquake. A unit increase in the scale corresponds to $10^{1.5}$ times higher released energy. While the magnitude is measurable with instruments, the intensity is an evaluation performed by experts based on the observable effects on humans, infrastructures, and objects.

The third data set includes socioeconomic, sociodemographic, and environmental characteristics of Italian municipalities between 2000 and 2015. In particular, the data set contains data on income levels, sourced from the Department of Finance of the Ministry of Economics and Finance, data on population size, age structure and environmental characteristics sourced from the Italian Institute for Statistics (ISTAT), and political characteristics sourced from the Italian Ministry of Interior. Moreover, we use data on minimum and maximum housing prices (per square meter) provided by the Real Estate Market Observatory of the Italian Revenue Agency. These data are collected twice a year and are complete since the second semester of 2003. All monetary values are deflated using the consumer price index to obtain real values at 2010 prices.[13]

The total number of observations (municipality × year) is 127,952. Balance sheet data and political variables are not complete for 8,136 observations. Therefore, our final data set is an unbalanced panel composed of 119,816 observations.

3.2 | Measurement of earthquake occurrence

Two measures of earthquake occurrence can be used to identify municipalities affected by earthquakes (treated municipalities): the magnitude and the intensity. The magnitude is an objective measure of the strength of an earthquake and its ability to serve as a proxy for damages to human and physical capital may be questioned. Since the magnitude is a space-invariant measure, some assumptions on the propagation of the effect in terms of distance and direction are required to assign earthquake events to municipalities. Generally, the propagation of earthquake waves depends on the depth of the epicenter and on the characteristics of the soil. Instead, intensity is the result of the evaluation of the observable impact performed by experts, who usually inspect disaster areas immediately after the shock. One cannot exclude that this evaluation is to some extent affected by subjective judgment driven by emotional involvement (e.g., attachment to the disaster area or to people who live there) or even corruption (e.g., the overestimation of the impact of an earthquake could allow to attract more financial resources from upper-level governments). However, intensity is assessed for each municipality affected by an earthquake and allows easily to identify towns affected by damages due to the shock. In our analysis, we prefer the intensity-based measure of earthquake occurrence because this is a qualitative measure of the local impact of an earthquake and varies among municipalities. The use of fixed effects in our econometric models should address any claim of systematic bias in the measurement of earthquake occurrence due to subjective judgment correlated with the geographical/institutional setting. More than that, we perform robustness checks of our results based on the described magnitude-based measure of earthquake occurrence under different assumptions of propagation. We provide a more detailed description of this approach later on in Section 5.1.1.

We assign treatment if a municipality is struck by at least one earthquake with intensity ≥ 5 in a given year. We choose this threshold because 5 is the lowest intensity level at which damages usually occur, and because it is the minimum intensity level for which we have complete data. Then, we define a set of treatment dummies $EQ_{i,t-j} = 1$, where i denotes the municipality and t the year, if the local maximum intensity of earthquakes occurred in the year $t - j$ (with $j \geq 0$) is ≥5. This set of variables allows to capture the impact of an earthquake at different points in time before the current year t. Our treatment variables show that 2,658 municipalities are struck by an earthquake at least once over the period 1985–2015, and 1,129 out of these municipalities are affected at least once over the period 2000–2015.

3.3 | Descriptive evidence

As preliminary suggestive evidence we compare the per capita local government expenditure of municipalities struck by at least one earthquake over the period 1985–2015 with the expenditure of municipalities that did not face any earthquake during the same period. Figure 2 shows that, on average, municipalities affected by earthquakes spend more than other municipalities, with a mean difference for the period 2000–2015 of 106 euro

[13]For the years 2000 and 2001 currency values expressed in Italian Lira were converted to euro using the fixed exchange rate of 1,936.27.

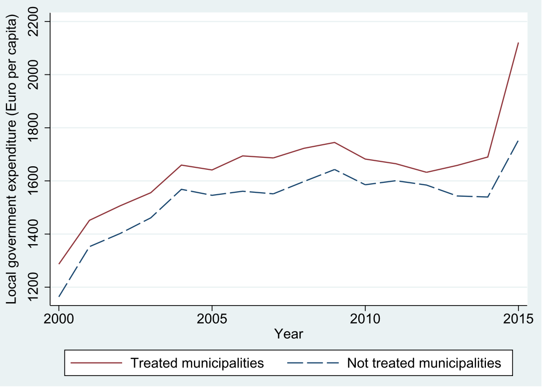

FIGURE 2 Per capita local government expenditure over time (2000–2015). The graph compares the average per capita local government expenditure for the period 2000–2015 of 2,658 municipalities struck by at least one earthquake with intensity ≥ 5 over the period 1985–2015 (red solid line) with 5,339 municipalities not struck by an earthquake over the same period (blue dashed line). Expenditure is discounted at 2010 prices. *Source:* Our elaboration on balance sheet data of Italian local governments for the period 2000–2015 provided by the Italian Ministry of Interior and data from the DBMI15 database of the Institute for Geophysics and Volcanology (Locati et al., 2016) [Color figure can beviewed at wileyonlinelibrary.com]

per individual at 2010 prices. In 2015, local governments increased expenditure by 10% on average because the central government loosed the constraints on capital expenditures, which were limited as a consequence of the economic crises to attempt to reduce public debt. Clearly, we cannot exclude that this difference is due to factors other than earthquake occurrence, such as institutional differences or historical spending behavior. Indeed, local government expenditure varies both across and within Italian regions, which may be due to factors such as geographical and institutional characteristics and economic development (see Figure A.1 in appendix).

To identify the impact of earthquakes on local government expenditure, it would be desirable to observe the same municipality under the two scenarios of treatment (earthquake occurrence) and no treatment. Clearly, this is not possible but may not represent a problem if earthquakes are randomly assigned to municipalities. The assumption of random assignment is challenged by earthquake occurrence over time since some areas are more exposed than others. However, a matching procedure that enhances the comparability of municipalities may grant sufficient strength to the analysis. Therefore, we sharpen the evidence of Figure 2 and reduce the unobserved variability, by comparing municipalities that are similar in the period before the occurrence of an earthquake. To do this we construct a counterfactual group of municipalities that allow us to analyze post-treatment variations of spending levels and to claim a causal relationship with earthquakes. Figure 3 illustrates the average spending trend of 347 treated municipalities, before and after the occurrence of a shock, with 347 matched municipalities. We identify matched municipalities with coarsened exact matching on average financial, sociodemographic and socioeconomic pre-treatment characteristics, the propensity to face an earthquake, and historical earthquake experience (see the Appendix A.1 for further information on the matching procedure and Table A.1 for the balancing properties). Note that, before treatment occurs, average per capita local government expenditure is almost identical in the two groups. Starting from the first year after the treatment period (period zero), expenditure sharply diverges. Treated municipalities seem to spend much more than the counterfactual group. Spending trends start to converge again from the seventh year after the disaster, though not completely.

Table 1 provides some descriptive statistics on the characteristics of 1,129 municipalities struck by an earthquake over the period 2000–2015 and 5,339 unaffected municipalities. We observe that in the year before the occurrence of an earthquake, municipalities do not significantly differ in terms of per capita expenditure and revenues, while the revenue composition tends to differ in treated municipalities. Treated municipalities collect less

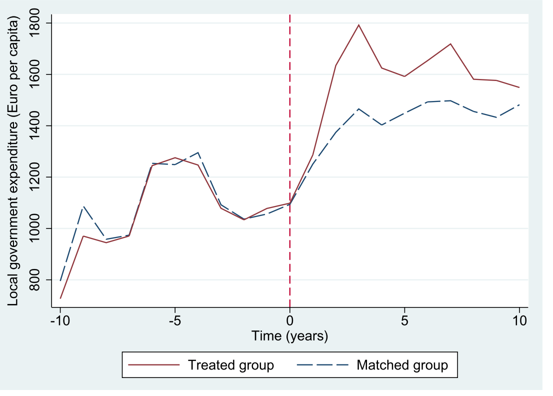

FIGURE 3 Expenditure variation after the occurrence of an earthquake. The graph compares the average per capita local government expenditure before and after the occurrence of an earthquake, which occurs at time zero, with expenditure of matched municipalities (without an earthquake) in the same year. Treatment is assigned if an earthquake with intensity ≥ 5 occurred over the period 2000–2015. The red solid line represents 347 treated municipalities, while the blue dashed line represents 347 matched municipalities identified with coarsened exact matching performed on average pretreatment characteristics of municipalities (institutional, sociodemographic, and environmental). Both groups include only municipalities with complete expenditure data for the period 2000–2015. Positive (negative) values on the x-axis indicate years after (before) the treatment. Expenditure is discounted at 2010 prices. *Source:* Our elaboration on balance sheet data of Italian local governments for the period 2000–2015 provided by the Italian Ministry of Interior and data from the DBMI15 database of the Institute for Geophysics and Volcanology (Locati et al., 2016). [Color figure can beviewed at wileyonlinelibrary.com]

local taxes than the control group, which could be due to the lower household income and the higher share of low-income population.[14] The lower amount of local tax revenues is partially offset by increased transfers of financial resources from the central and regional governments. The aggregate revenues from local taxation and transfers account for about 60% of total revenues.

After an earthquake, both local government expenditure and revenues significantly increase by 198 and 185 euro per capita, respectively. The immediate increase of revenues allows to limit losses. Additional revenues are composed for more than 60% of transfers from the central and regional governments. Revenues from local taxation, instead, do not vary significantly on average. As for the population size and age structure, treated municipalities are almost twice as populated as other municipalities and, before the shock, they have a slightly higher fraction of the youngest and oldest age cohorts. Population size does not significantly vary after the shock, but the age structure changes since the percentage of young people tend to shrink, while the elderly share increases. This could suggest that elderly people are less mobile because of physical limitations, or stronger emotional attachment to their town.

This preliminary evidence suggests that the comparison of expenditure levels between municipalities affected and not affected by earthquakes should carefully address differences in terms of characteristics that could confound expenditure variations. The following empirical strategy controls for those observable characteristics as well as other unobservable time-invariant characteristics.

[14]We define the share of low-income population as the share of individuals earning a yearly income less than or equal to 10,000 euro. Note that our income data are structured in eight income classes and for each class we have information on the total amount of income and the number of individuals. According to our definition, the low-income individuals are those of the two lowest income classes representing about 39% of the total number of individuals.

TABLE 1 Descriptive statistics: Municipality characteristics

		Treated group	
	Control group	Before	After
	(1)	(2)	(3)
Expenditure p/c	1,509.7	1,332.1**	1,664.1***
	(1,647.6)	(861.9)	(1,517.1)
Revenues p/c	1,624.7	1,674.4	1,833.3**
	(1,686.7)	(1,041.0)	(1,583.5)
Transfers p/c	550.9	623.5*	706.2*
	(881.1)	(706.5)	(903.3)
Tax revenues p/c	420.4	340.9***	344.1
	(305.3)	(196.7)	(184.9)
Average income	16,504.4	14,966.0***	15,296.9
	(3,799.4)	(3,728.9)	(3,609.5)
% Low-income population	38.79	47.68***	45.44***
	(13.26)	(14.51)	(13.65)
Population	6,260.8	11,714.2***	10,479.5
	(26,275.1)	(88,876.1)	(79,286.5)
% Young (0–14 years)	13.19	13.40*	12.94***
	(2.865)	(3.169)	(3.007)
% Old (≥65 years)	21.99	22.65**	23.41**
	(6.150)	(6.755)	(6.412)
Partial mountain jurisdiction	10.11%	9.83%	
Mountain jurisdiction	53.59%	54.03%	
Coastal jurisdiction	10.68%	6.55%	
Observations	84,521	920	1,165
Municipalities	5,339	1,129	

Note: It presents mean characteristics of municipalities struck by earthquakes (treated group) with intensity ≥ 5 over the period 1985–2015 and mean characteristics of unaffected municipalities (control group). Column 1 presents means for the period 2000–2015, and columns 2 and 3 present means for the year before and the year after an earthquake occurs, respectively. If a municipality is affected by multiple earthquakes within three consecutive years, we aggregate the events and define the before-period as the year before the first shock and the after-period as the year after the last shock. This excludes the overlapping of observations on expenditure for the year after the first event and the year before the following event for the same municipality. Stars in column 2 indicate significance levels of *t* tests on mean differences between columns 1 and 2. Stars in column 3 indicate significance levels of *t* tests on mean differences between columns 2 and 3. For the last three variables, we show sample frequencies because they are time-invariant. Standard deviations are in parentheses. Monetary values are discounted at 2010 prices.
***$p < .001$.
**$p < .01$.
*$p < .05$.

4 | EMPIRICAL STRATEGY

4.1 | Earthquakes and spending levels

To assess the impact of earthquakes on local government expenditure, we employ a flexible estimation strategy most closely aligned with the literature on event-study estimation (e.g., Gallagher, 2014) and regress per capita expenditure against earthquake measures and control for characteristics of municipalities and local institutions that may affect spending levels as well as for time-invariant heterogeneity.[15] We specify the following model:

$$y_{it} = \mathbf{T}'_{it}\boldsymbol{\alpha} + \mathbf{x}'_{it}\boldsymbol{\beta} + \theta_t + \gamma_i + \varepsilon_{it}, \tag{1}$$

where y_{it} is the natural logarithm of per capita expenditure of municipality i in year t. $\mathbf{T}'_{it}$ is a vector of treatment variables, that is, earthquake indicators, and $\mathbf{x}'_{it}$ is a vector of time-varying controls, including the intercept term. Controls ($\mathbf{x}'_{it}$) include income, population age structure, geographic and political characteristics, and funding sources from the central and regional governments. $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are the vectors of parameters to be estimated. θ_t are time fixed effects, γ_i is a municipality-specific time-invariant element, and ε_{it} is the idiosyncratic error term.

In our baseline specification $\mathbf{T}'_{it}\boldsymbol{\alpha}$ is defined as

$$\mathbf{T}'_{it}\boldsymbol{\alpha} = \sum_{j=0}^{1} \alpha_j EQ_{i,t-j} + EQ_{i,t-d} \times (\alpha_{d1} Dist_{it} + \alpha_{d2} Dist_{it}^2 + \alpha_{d3} Dist_{it}^3), \tag{2}$$

where $EQ_{i,t-j}$ and $EQ_{i,t-d}$ are the dummy treatment variables described in Section 3.2. More precisely, the two terms in the summation, EQ_{it} and $EQ_{i,t-1}$, capture the effect of an earthquake occurred in the current year and 1 year before, respectively. The shocks occurred earlier (more than 1 year before) are captured by $EQ_{i,t-d}$, where d is the temporal distance from the most recent earthquake before $t-1$ ($1 < d \leq 15$). We define $Dist_{it} = d$ if $EQ_{i,t-d}$ is equal to one, and zero otherwise. Therefore, the distance polynomial of third degree (within brackets) is a nonlinear time-trend capturing medium-run marginal effects of earthquakes on expenditure. We consider a nonlinear time trend to capture a possible inverse U-shaped effect and a tail of earthquakes on expenditure.[16] Indeed, our descriptive statistics suggest that expenditure initially grows and then tends to converge to pre-treatment levels. We impose $Dist_{it} \leq 15$ since beyond this period we generally observe a convergence of expenditure to pre-treatment levels, as suggested by the descriptive statistics in Section 3.3.[17]

The covariates that compose the vector $\mathbf{x}'_{it}$ are a set of time-varying financial, political, socioeconomic, and sociodemographic variables, and a set of time-invariant environmental characteristics. Financial variables include the natural logarithm of per capita transfers from the central and regional governments, and the natural logarithm of per capita revenues from local taxation. Political variables include the vote-share concentration of the local government council, the number of years before municipal elections, a dummy variable equal to one if the incumbent government is center-right oriented, and a dummy variable equal to one if the incumbent mayor reached his term limit. Socioeconomic variables include the natural logarithm of average yearly per capita income and the share of low-income population, and sociodemographic variables include the share of the youngest (0–14 years) and oldest (≥65 years) age cohorts. Environmental characteristics are captured by dummy variables equal to one indicating whether a municipality is a partially mountainous jurisdiction, a mountainous jurisdiction, or a coastal jurisdiction.

To estimate the parameters of our model we use three methods: pooled ordinary least squares (OLS), random effects, and fixed-effects regressions. Pooled OLS provides consistent parameters but treats observations as mutually independent and does not account for serial dependence of observations. Hence, the main limitation of the pooled OLS model is that possible unobserved heterogeneity among municipalities is neglected ($\boldsymbol{\gamma}_i = 0$).

[15]The literature has suggested several features of local governments that are likely to affect the expenditure; see, for instance, Gennari and Messina (2014) and Lundqvist (2015).

[16]We use a third-order polynomial time trend because, according to preliminary findings, it is the most suitable specification to capture the effect of an earthquake on local government expenditure. Indeed, in what follows we use also a model specification including yearly lags of earthquake occurrence measures (see Section 5.2).

[17]Preliminary findings suggest that spending levels tend to converge to predisaster levels between the 10th and the 15th year after an earthquake. Moreover, the impact of an earthquake is fully observed for a maximum of 15 periods in our panel.

However, both OLS and random-effects regressions include a region-specific time-invariant effect.[18] The random-effects model treats unobserved heterogeneity of municipalities as a random shock and requires the assumption that $\boldsymbol{\gamma}_i$ is iid. The fixed-effects model relaxes this assumption by allowing $\boldsymbol{\gamma}_i$ to be correlated with the other exogenous variables, but it does not allow to include environmental time-invariant characteristics and region fixed effects.[19] The random-effects model is more efficient, but if the assumption on the independence of the time-invariant error is violated, the estimates are biased. In that case, the fixed-effects model should be preferred because it estimates consistent parameters. Since several unobserved factors could lead to differences in spending levels (e.g., geographic characteristic, touristic attractiveness, and economic development), we expect the fixed-effects model to be more appropriate. We formally test this assumption using the Hausman test.

In addition, we specify a first-order autoregressive model and include the lag of the dependent variable as a regressor in Equation (1). This specification allows to capture the persistence of local government expenditure that may be driven by historic and institutional factors. We estimate this model with municipality fixed effects. Since serial correlation and heteroskedasticity may affect the estimation of the standard errors, we use robust standard errors clustered by municipality in all specifications.

An issue that needs to be discussed is the possible endogeneity of upper-level government transfers. In Equation (1), we assume that transfers are exogenous, and hence transfers lead to a variation of local government expenditure because more resources are available, as literature in this field suggests (e.g., Gennari & Messina, 2014; Revelli, 2006). However, variations of transfers from upper-level governments may not be completely exogenous to expenditure variations if they are influenced by higher spending requirements (Lundqvist, 2015) or by the ability of politicians to attract financial resources from upper-level governments (Galletta, 2017). In this case, OLS and GLS estimates could be biased because the assumption on the independence of the error term ($E[\varepsilon_{it} \mid \mathbf{X}]=0$) is violated. The within-estimator of the fixed-effects model partially accommodates this problem since it accounts for time-invariant factors that lead to the endogeneity of transfers. We further address this issue by a two-stage instrumental variable (IV) approach discussed in Section 5.1.

Furthermore, we need to address two other possible sources of bias. First, if other regressors, such as income, are possibly influenced by a disaster, then the estimated coefficients of earthquake occurrence may be biased. To test the extent to which this issue may affect our results, we estimate Equation (1) with and without controls ($\mathbf{x}'_{it}$). Second, due to the way in which earthquakes propagate, spatial correlation may bias our estimates if neighboring local governments affected by a disaster adjust their spending levels, which may generate some spillover effects. To consider the spatial correlation of earthquakes and account for possible collinearity between the intensity of earthquakes in neighboring municipalities, we include two spatial-lag measures of earthquake events in our regressions. These variables, $EQ_{-i,t}$ and $EQ_{-i,t-1}$, are based on the spatial matrix of bordering municipalities and are equal to one if an earthquake occurred in some neighboring municipality, respectively in the current and the previous period.[20]

We test the robustness of our identification strategy by defining other criteria for the assignment of treatment. We use different earthquake-intensity thresholds and magnitude-based measures to define treated municipalities. Note, however, that raising the intensity threshold implies a reduction in the number of treated municipalities. Over the period 2000–2015, municipalities struck by an earthquake with intensity ≥ 6 are 213, and only 46 with

[18]Note that region-specific time-invariant effects account for heterogeneity between ordinary and autonomous regions with special statute (i.e., the regions Valle D'Aosta, Friuli Venezia Giulia, Sicily and Sardinia, and the provinces of Bolzano and Trento), such as differences in the funding mechanism of public expenditure. Moreover, conditional on region-specific time-invariant effects, our regression results are not sensitive to the inclusion/exclusion of autonomous regions with special statute.

[19]Two municipalities of the region Marche became part of Emilia-Romagna in 2010. However, this change is not significant.

[20]Boustan, Kahn, Rhode, and Yanguas (2017) use a different approach to account for spatial correlation. They use a single disaster index for both affected and neighboring unaffected US counties that combines information on disasters occurred in a US county with distance-weighted information on shocks occurred in neighboring counties. Since we are interested in estimating the impact of a local earthquake over time, this strategy would complicate the interpretation of our results.

intensity ≥ 7. Such a low number of treated municipalities could have some drawbacks in the econometric estimation. If we raise the intensity cut-off and sharpen our sample of affected municipalities we expect to observe a larger impact of earthquakes on expenditure. To further confirm our evidence, we repeat the analysis using the sharper sample of matched municipalities defined in Section 3.3, which is likely less exposed to unobserved heterogeneity but also more prone to dim the effect due to proximity between treated and matched municipalities. Finally, we test the sensitivity of our results by excluding/including municipalities struck by a disaster according to the timing and frequency of earthquake occurrences (see Section 5.1.1 for details).

4.2 | Asymmetric and heterogeneous responses to grants

Descriptive evidence in Section 3.3 suggests that central and regional governments largely contribute to local disaster relief through the transfer of financial resources to municipalities. To better understand how earthquakes, local government expenditure and transfers are related to each other, we run a preliminary analysis using two models, where the dependent variable is either local government expenditure (as in the previous Equation (1)) or transfers. To see the impact of earthquakes in different years, we use a linear vector of all earthquake occurrence dummies in the last 12 years, $\mathbf{T}'\boldsymbol{\alpha} = \sum_{j=0}^{11} \alpha_j EQ_{t-j}$, instead of the polynomial specification of Equation (2). Therefore, we estimate the yearly ATT of an earthquake on both expenditure and transfers. We limit the analysis to the 11th year after the disaster since previous results suggest that after that period the effect of one single earthquake is negligible.[21]

One interesting aspect on the effect of grants is the comparison between earthquake-related grants (mostly matching grants) and other types of grants (mostly unconditional grants). The literature on flypaper effects generally suggests that matching grants have greater influence on expenditure than unconditional grants, since the former combine an income and a substitution effect (Gramlich, 1977).[22] To provide empirical evidence on the flypaper effect in Italy, Gennari and Messina (2014) focus on unconditional grants and, therefore, try to exclude outlier observations due to shocks to avoid any confounding factor related to matching grants. We can contrast this approach by exploiting the large and unique data set of earthquake occurrences to separate (earthquake-specific) matching grants from unconditional grants. This allows us to disentangle heterogeneous flypaper effects and asymmetric responses to different types of grants. Since data on earthquake-specific grants are limited and incomplete, we use the control group of not treated municipalities identified by the matching procedure above to predict the average growth rate of (unconditional) transfers if earthquakes would not have occurred.[23,24]

We can now use predicted grants of different types to expand the linear flypaper effect model (Gennari & Messina, 2014) as follows:

$$Y_{it} = \alpha_1 MG_{it} + \alpha_2 MA_{it} + \alpha_3 UG_{it} + \alpha_4 UA_{it} + \mathbf{X}_{it}'\boldsymbol{\beta} + \theta_t + \gamma_i + \varepsilon_{it}, \quad (3)$$

where Y_{it} is the level of per capita expenditure of municipality i in year t, MG_{it} is the level of (earthquake-specific) matching grants, and UG_{it} is the level of unconditional grants. $\mathbf{X}_{it}'$ is the vector of control variables as in Section 4.1 θ_t and γ_i are time and municipality fixed effects, and ε_{it} is an iid error term.

The variables MA_{it} and UA_{it} measure the decrease of matching and unconditional grants relative to the previous year ($t-1$), respectively, and are specified as $MA_{it} = MD_{it}(MG_{it} - MG_{i,t-1})$ and $UA_{it} = UD_{it}(UG_{it} - UG_{i,t-1})$, with MD_{it} and UD_{it} being dummy variables equal to one if the respective grants are decreasing, and zero otherwise.

[21]We also perform the analysis with $j = 15$, but coefficients for $j > 11$ are not significant.

[22]This is because public goods relative prices tend to fall, which shifts resources away from private goods.

[23]Balance sheet data does not allow to identify transfers received for disaster relief. The Department of the Civil Protection provides reports on the allocation of earthquake relief funds, but these documents cover only the period 2012–2015 and detailed information on the resources received by each local government is not always available.

[24]Barone and Mocetti (2014) compare the effects of two large earthquakes in Italy by means of a synthetic control approach based on regional data.

Therefore, MA_{it} and UA_{it} capture the asymmetric response of expenditure to variations in the two types of grants. In accordance with Gennari and Messina (2014), not significant estimates of the parameters α_2 and α_4 imply that local governments react similarly to increases and decreases in transfers. Conversely, significant estimates of α_2 and α_4 imply that $\alpha_1 + \alpha_2$ measures the expenditure response to decreasing matching grants, and $\alpha_3 + \alpha_4$ is the response to decreasing unconditional grants. Negative and significant parameters α_2 and α_4 suggest that local government expenditure is more sensitive to increases than to decreases in transfers, while positive and significant estimates suggest the opposite. In the literature on flypaper effect, the former type of response is known as the "fiscal replacement" effect (Gramlich, 1987), while the latter type of response is the so-called "fiscal restraint" effect (Gamkhar & Oates, 1996).

The final part of our empirical strategy hypothesizes that the response of local governments to earthquake shocks differs across the country, between northern and southern municipalities. To this aim, we modify the above Equation (3) to include the interaction terms between grants (both unconditional and earthquake-specific grants) and a dummy variable equal to one if a municipality is located in southern regions, namely, Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, and Sicily.[25] The two asymmetry variables are now dropped.[26] For simplicity, we will use north and northern to refer to all other regions. A further distinction between North and Center has been considered but did not provide significant differences.

5 | RESULTS

5.1 | The impact on spending levels

The effect of earthquake shocks on local government spending from the estimation of Equation (1) using pooled OLS, random effects, fixed effects, and autoregressive fixed-effects regressions is summarized in Table 2.[27] Since the dependent variable, that is, the per capita local government expenditure, is log-transformed, percentage changes in expenditure after the occurrence of an earthquake are obtained by $100 \times (e^{\hat{\alpha}_j} - 1)$. The coefficients of earthquake occurrence in the current and the previous year (EQ_t and $EQ_{t\text{-}1}$) can be interpreted as average treatment effects on treated municipalities (ATT). The coefficients of all treatment variables are highly significant, slightly less for the immediate effect EQ_t. The OLS results are basically in line with panel data models although repeated observations over time and possible correlation between the treatment variables and unobserved characteristics of municipalities are not taken into account. Only the coefficient of the immediate effect, EQ_t, is likely overestimated.

The estimates from the random- and fixed-effects models are very similar. However, we can easily reject the null hypothesis of the Hausman test.[28] Thus, the fixed-effects model is preferred. The fixed-effects specification controls for time-invariant municipality-specific characteristics such as geographical seismic zones.[29] All the coefficients are slightly lower in the autoregressive specification (column 4), which suggests that earthquake measures partially capture the effect of persistent spending.

In the fixed-effects specifications, the immediate impact of an earthquake on local government expenditure is between 1.92% and 1.95%, which roughly corresponds to 27–28 euro per capita. After 1 year, the effect of the shock is three times larger with a shift of local government expenditure between 6.20% and 6.82% (100–112 euro per capita). This is an expected result for a developed country according to Noy and Nualsri (2011). Since local

[25]This classification is provided by ISTAT, except for Sicily which is classified as Island together with Sardinia. However, Sicily is commonly identified as a southern region because of its geographical location and cultural and environmental aspects.

[26]Note that the two asymmetry variables are not significantly different between municipalities in the North and in the South (results not reported here).

[27]Note that the lag of the dependent variable in the autoregressive model is grouped with the financial time-variant controls.

[28]The Hausman test returns the statistic $\chi^2(29) = 10{,}861.41$, and the critical value in a 99.9% confidence interval is $\chi^2_{0.001}(29) = 58.30$.

[29]Note, however, that the inclusion of seismic zones into OLS and random-effects models does not affect the results.

TABLE 2 Impact of earthquakes on local government expenditure

	OLS (1)	RE (2)	FE (3)	FE (AR1) (4)	IV_FE (5)
EQ_t	0.0278** (0.0107)	0.0179* (0.00828)	0.0193* (0.00860)	0.0190** (0.00736)	0.0139 (0.00935)
EQ_{t-1}	0.0650*** (0.0110)	0.0632*** (0.00945)	0.0660*** (0.00976)	0.0602*** (0.00808)	0.0553*** (0.00949)
$EQ_{t-d} \times Dist$	0.0241*** (0.00402)	0.0285*** (0.00375)	0.0305*** (0.00398)	0.0166*** (0.00254)	0.0186*** (0.00387)
$EQ_{t-d} \times Dist^2$	−0.00283*** (0.000636)	−0.00409*** (0.000593)	−0.00456*** (0.000617)	−0.00261*** (0.000405)	−0.00253*** (0.000610)
$EQ_{t-d} \times Dist^3$	0.0000797** (0.0000264)	0.000142*** (0.0000245)	0.000163*** (0.0000252)	0.0000966*** (0.0000170)	0.0000782** (0.0000253)
Observations	119,816	119,816	119,816	119,102	112,153
Overall R^2	0.685	0.648	0.383	0.760	0.433
Within R^2		0.594	0.599	0.663	0.445
Between R^2		0.687	0.279	0.825	0.422
Region fixed effects	Yes	Yes	No	No	No
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Financial time-variant controls	Yes	Yes	Yes	Yes	Yes
Political controls	Yes	Yes	Yes	Yes	Yes
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes
Sociodemographic controls	Yes	Yes	Yes	Yes	Yes
Environmental controls	Yes	Yes	No	No	No
Hausman test					666.9***
Endogeneity test					40.61***

Note: It presents regression results for the log of per capita local government expenditure. Model 1 is a pooled OLS regression, Model 2 is random-effects regression, Models 3 and 4 are fixed-effects regressions, and Model 5 is a two-stage fixed-effects regression where log-transfers are instrumented with the second lag of log average transfers received by neighboring municipalities. EQ_t and EQ_{t-1} are dummy variables equal to one if there has been an earthquake in the current year and in the previous year, respectively, and zero otherwise. EQ_{t-d} is a dummy variable equal to one measuring the occurrence of the latest earthquake within the last 15 years, and zero otherwise. $1 < d \leq 15$ measures the temporal distance from the latest earthquake. All models control for financial time-variant (logs of per capita transfers from the central and regional governments and revenues from local taxation), political (center-right government, vote concentration, term limit, years before elections), socioeconomic (average income and percent of low-income population) and sociodemographic factors (population density, percent of young, and percent of old population), and year fixed effects. Models 1 and 2 further control for environmental characteristics (mountain, partial mountain, and coastal jurisdiction) and region fixed effects, which are time-invariant, and Model 4 for the lag of the dependent variable. Standard errors (in parentheses) are robust and clustered by municipality. Monetary values are discounted at 2010 prices.
Abbreviation: OLS, ordinary least squares.
***$p < .001$.
**$p < .01$.
*$p < .05$.

governments may not respond immediately to the shock and the budget needs some time to be adjusted, we observe that the impact is higher 1 year after the event. The local government may rather decide to respond immediately by changing the spending composition and reallocate the resources destined to services that cannot be offered anymore due to unavailable infrastructures or loss of human capital. Other spending categories (e.g., local services and social protection) may now require more resources to tackle the consequences of the seismic event. After 1 year the expenditure tends to increase because of investments in disaster relief, for example, cleaning, reconstruction, and reimbursement of damages to citizens. Moreover, the delay in the increase of expenditure may be due to the timing of external aid from upper-level governments and from charity.

Differences in spending levels between treated and unaffected municipalities are not limited to the short run. The first-, second-, and third-order interaction terms between earthquake occurrence and time passed since the latest shock suggest that the effect on spending levels tends to increase in the years after the event, but then expenditure slowly converges to pre-disaster levels (negative coefficient of second-order interaction and positive coefficient of the third-order interaction). The estimates show that expenditure continues to grow until 4–5 years after the disaster and then regresses to pre-disaster levels after 11–12 years.[30]

To correct the estimates for possible endogeneity of transfers from central and regional governments, we use an IV approach and estimate the model in column 3 using 2SLS and the second lag of transfers received by neighboring jurisdictions as an exogenous instrument.[31] The estimates for the parameters are reported in column 5. Diagnostic tests confirm that transfers are endogenous and that the IV specification provides consistent estimates compared to the fixed-effects specification. The coefficients of all earthquake occurrence variables are lower in absolute values and EQ_t loses significance. This is most likely determined by the fact that transfers from central and regional governments increase when an earthquake occurs and, given that the first-stage regression of the IV approach accounts also for earthquake variables, exogenous transfers in the second-stage regression capture part of the effect of an earthquake on expenditure. Nevertheless, the coefficients still show that the effect of an earthquake on expenditure lasts for 11–12 years.

To account for the potential bias induced by the inclusion of time-varying controls possibly affected by earthquake shocks, such as income, we re-estimated Equation (1) excluding the full set of covariates (see columns 1 and 2 of Table A.2 in appendix). The estimated coefficients differ only slightly, and are very similar to the baseline results both in terms of magnitude and levels of significance. The only exception is the coefficient of the immediate impact of an earthquake (EQ_t) that is smaller and not significant, though still positive.[32]

Finally, the size of the estimated coefficients of EQ_t and $EQ_t - 1$ decreases only slightly when spillover effects are included in columns 3 and 4 of Table A.2. The immediate impact of natural disasters occurred in neighboring municipalities is not significant, but we observe a significant impact after 1 year. The latter spillover effect is about 28% of the effect of earthquakes occurred within the municipality borders.

5.1.1 | Robustness checks and sensitivity analysis

The robustness of our main results is ensured by two alternative approaches to identify the effect of earthquakes on local government expenditure. The first approach is based on the matching sample described in Section 3.3 (see also the Appendix A.1 for information on the matching procedure), while the second approach tests the sensitivity of our estimates on the full sample to the inclusion/exclusion of municipalities according to the timing and frequency of earthquake occurrences. Finally, we consider several different criteria for the assignment of treatment.

When we run regressions using the sample of matched municipalities (see Table A.3 in appendix) we obtain similar results, but the coefficients of the treatment variables and standard errors are slightly larger. This is because

[30]We compute the growing period by looking at the maximum of the estimated function defined by the two interaction terms $d = (-2\hat{\alpha}_{d2} - \sqrt{4\hat{\alpha}_{d2}^2 - 12\hat{\alpha}_{d1}\hat{\alpha}_{d3}})/6\hat{\alpha}_{d3}$ with $\hat{\alpha}_{d1}$, $\hat{\alpha}_{d2}$, and $\hat{\alpha}_{d3}$ being the estimates of the parameters α_{d1}, α_{d2}, and α_{d3} in Equation (2), respectively, and calculate the convergence period by computing the zeros of the same function ($d = (-\hat{\alpha}_{d2} - \sqrt{\hat{\alpha}_{d2}^2 + 4\hat{\alpha}_{d1}\hat{\alpha}_{d3}})/2\hat{\alpha}_{d3}$).

[31]Differences are negligible indeed if we repeat the estimation using the first or the second temporal lag of transfers instead of the spatial-temporal lag.

[32]Two-tailed hypothesis tests for coefficients differences between models with and without the full set of covariates do not show any statistically significant difference in the autoregressive fixed-effects specification. Conversely, statistically relevant differences are only observed for the coefficients of the first-, second- and third-order interaction terms between earthquake occurrence and time in the fixed-effects model.

the matching sample includes less heterogeneous municipalities and we exploit a limited number of struck units (347 of 1,129 municipalities struck between 2000 and 2015).

Then, we exclude from the full sample municipalities that are struck more than once by a disaster between 2000 and 2015 (see Table A.4, columns 1 and 2, in appendix), or municipalities that are struck in the 12 years before 2000 (columns 3 and 4), or municipalities struck by a disaster after 2009 (columns 5 and 6).[33] Again, the results are in line with our baseline findings. However, as expected, when we exclude municipalities struck by a disaster in the 12 years before 2000, the estimated coefficients and standard errors are generally larger because the sample of struck municipalities is composed of only 819 units. Moreover, our estimates may now suffer from a selection bias if the excluded municipalities are those more frequently struck by earthquakes and, therefore, more resilient. The estimates of the remaining sensitivity analysis are very close to our baseline results.

We run a third robustness check using higher minimum intensity levels (6 and 7 instead of 5) to assign treatment (see Table A.5, columns 1 and 2, in appendix). The results are in line with our baseline results, although the effects are much larger due to the focus on stronger earthquakes. Also, spending levels reach pre-treatment levels 15 years after the shock, 3 years later than previous estimates suggest.

Finally, we define earthquake occurrence measures based on the magnitude of the earthquake. We select earthquakes with moment magnitude ≥ 4 because this is the minimum magnitude for which the INGV includes earthquakes in the database. The magnitude is generally more objective than the intensity, but we need to assume that the energy released by an earthquake propagates homogeneously from the epicenter in all directions since it is measured at the epicenter only.[34] Therefore, we considered municipalities within some distance from the closest epicenter. In particular, we use 10, 20, and 30 km distance thresholds between the epicenter and the centroid of each municipality. As shown in Table A.5, columns 3–5, in appendix, our baseline results are confirmed. The estimates show that the greater the distance from the epicenter, the lower is the impact on local government expenditure (moving from column 3 to column 5). In particular, the model using the 20-km range for the assignment of treatment (column 4) provides similar estimates to those obtained in Table 2. This implies that municipalities struck with intensity ≥ 5 are located, on average, within 20 km from an epicenter with magnitude ≥ 4.

5.2 | The role of grants

The role played by grants from upper-level governments in raising expenditure following an earthquake is summarized by the results reported in Table 3. Column 1 shows fixed-effects estimates on the natural logarithm of per capita local government expenditure, and column 2 on the natural logarithm of per capita transfers. The coefficients of treatment variables are significant until the 10th year after the disaster for local government expenditure, similarly to the results obtained in Table 2, and until the 9th year for transfers. Moreover, transfers of financial resources grow initially faster than local government expenditure after an earthquake, and absolute per capita variations (in euro) show that transfers increase more than expenditure between the 2nd and the 7th year after an event (see columns 3 and 4 of Table 3).[35] This evidence is illustrated in Figure 4 with 95% confidence intervals. While the increase in per capita expenditure is roughly stable between the second and the 6th year after an earthquake, transfers from central and regional governments follow a different trend. Central and regional governments tend to respond immediately to the higher spending requirements of treated municipalities. Then, from 8 years after the event, additional transfers fall below the increase in expenditure. Overall, the increase in transfers overcomes the increase in expenditure.

[33] The latter exclusion allows at least 6 years of lag for each municipality struck by a disaster, which corresponds to half of the estimated impact period of an earthquake on expenditure. Using a more complete set of lagged effects improves our year fixed-effects specification since we limit the risk that measured lag effects are due to specific economy-wide effects in different time periods.

[34] In 2017, an earthquake struck the isle of Ischia in the Campania region with a relatively low magnitude of 4, but caused relevant damages.

[35] We transform the estimates of the treatment variables in columns 1 and 2 into real per capita variations using $\hat{ATT}_{t-j} = (1 - e^{-\hat{\alpha}_j})\bar{y}_{t-j}$, with y identifying either per capita expenditure or per capita transfers at 2010 prices, $\bar{y}_{t-j} = E[y_{it}|EQ_{i,t-j} = 1]$, and $\hat{\alpha}_j$ being the estimated coefficients of EQ_{t-j}.

Over the overall period (11 years), treated municipalities spend 962 euro per individual more than not affected municipalities, while per capita transfers are 1,201 euro higher. Hence, transfers of financial resources from central and regional governments seem to exceed expenditure by 239 euro per individual. If we consider that the average population of a treated municipality between 2000 and 2015 is about 10,000 individuals and 1,129 municipalities are struck by an earthquake, the difference between transfers and expenditure amounts to almost 2.7 billion euro. Generally, policy-makers at central and regional levels allocate grants to municipalities affected by earthquakes mainly in the form of matching transfers. Although local governments are supposed to make use of these resources over time, some amount remains on hold and does not translate into higher expenditure for several years. Actually, an effective monitoring system on how resources are spent is still not in place, and transfers may also partially compensate lower revenues from local taxation, since the central government can allow to postpone the payment of taxes for people residing in disaster areas.

5.3 | Flypaper effect and asymmetric response

The effects of earthquake-related grants (matching grants) and unconditional grants on local government spending are compared in Table 4. This table reports the results from fixed-effects regressions using Equation (3). In column

TABLE 3 Impact of earthquakes on local government expenditure and transfers by year

	Log		Euro per capita	
	Exp. (1)	Transf. (2)	Exp. (3)	Transf. (4)
EQ_t	0.0280***	0.0901***	38.82	62.69
	(0.00835)	(0.0225)		
EQ_{t-1}	0.0746***	0.162***	117.2	110.2
	(0.00941)	(0.0232)		
EQ_{t-2}	0.0664***	0.206***	114.0	157.7
	(0.00899)	(0.0238)		
EQ_{t-3}	0.0616***	0.221***	95.80	174.5
	(0.00831)	(0.0227)		
EQ_{t-4}	0.0616***	0.248***	102.6	235.4
	(0.00814)	(0.0231)		
EQ_{t-5}	0.0771***	0.196***	135.5	137.6
	(0.00854)	(0.0190)		
EQ_{t-6}	0.0688***	0.210***	129.5	147.1
	(0.00843)	(0.0193)		
EQ_{t-7}	0.0415***	0.134***	73.31	88.21
	(0.00727)	(0.0176)		
EQ_{t-8}	0.0312***	0.0653***	53.29	42.00
	(0.00686)	(0.0185)		
EQ_{t-9}	0.0332***	0.0772***	54.16	46.19
	(0.00644)	(0.0173)		
EQ_{t-10}	0.0251***	0.0192	36.61	11.37
	(0.00576)	(0.0162)		

(Continues)

TABLE 3 (Continued)

	Log		Euro per capita	
	Exp.	**Transf.**	**Exp.**	**Transf.**
	(1)	**(2)**	**(3)**	**(4)**
EQ_{t-11}	0.00788	−0.0187	11.57	−10.93
	(0.00529)	(0.0145)		
Observations	119,816	119,837		
Overall R^2	0.384	0.154		
Within R^2	0.599	0.436		
Between R^2	0.281	0.0323		
Municipality fixed effects	Yes	Yes		
Year fixed effects	Yes	Yes		
Financial time-variant controls	Yes	No		
Political controls	Yes	Yes		
Socioeconomic controls	Yes	Yes		
Sociodemographic controls	Yes	Yes		

Note: It presents fixed-effects regression results for the log of per capita local government expenditure (column 1) and the log of per capita transfers from central and regional governments (column 2). Columns 3 and 4 transform regression results in real per capita values. EQ_{t-j}, with $0 \leq j \leq 11$, is a dummy variable equal to one if the latest earthquake occurred *j* years before the current year, and zero otherwise. Model 1 controls for financial time-variant factors (logs of per capita transfers from the central and regional governments and revenues from local taxation), and both models control for political (center-right government, vote concentration, term limit, years before elections), socioeconomic (average income and percent of low-income population) and sociodemographic factors (population density, percent of young, and percent of old population), and year fixed effects. Standard errors (in parentheses) are robust and clustered by municipality. Monetary values are discounted at 2010 prices.
$^{***}p < .001$.
$^{**}p < .01$.
$^{*}p < .05$.

1 the two asymmetry variables are initially excluded from the estimation. Note that both earthquake-specific and unconditional grants stimulate expenditure more than income does. The expenditure response to one additional euro of unmatching grants is almost 13 times larger than the response to income.[36] Our estimated coefficient is slightly different from the coefficient estimated by Gennari and Messina (2014). This is because we use a fixed-effects specification and data for a different period, and aggregate central and regional government transfers and current and capital transfers. However, our results are similar to the results obtained by Gamkhar and Oates (1996). Although the impact of matching grants is more than five times the effect of income, the multiplier is smaller than the multiplier of unconditional grants (about half). This is apparently surprising since the theory suggests that specific transfers should have at least the same effect on expenditure as unconditional transfers (Bailey & Connolly, 1998). However, as we will see later in Section 5.4, this is an average effect that does not account for heterogeneity in the response across the country, likely due to remarkable variation of efficiency in the use of earthquake-specific transfers.

In column 2, we extend the model to include the two asymmetry variables that capture different effects between increasing and decreasing transfers. The negative and significant coefficient of the asymmetry variable relative to unconditional grants suggests that there is a replacement effect when transfers decrease, that is,

[36]The coefficient of unmatching grants does not change if we estimate Equation (3) using only the subsample of municipalities not affected by earthquakes.

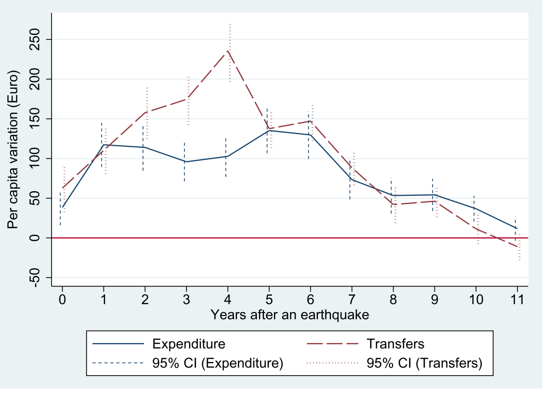

FIGURE 4 Variation of local government expenditure and transfers after an earthquake. The graph represents the estimates of the impact of an earthquake with intensity ≥ 5 on per capita local government expenditure (blue solid line) and per capita transfers of financial resources from central and regional governments (red dashed line) for a 12-year period after the occurrence of an earthquake. Vertical blue dashed and red dotted segments are 95% confidence intervals for the estimates of expenditure and transfers, respectively. Local government expenditure is adjusted for time-variant financial, political, socioeconomic, and sociodemographic factors, and municipality and time-fixed effects. Transfers are adjusted for time-variant socioeconomic and sociodemographic factors, and municipality- and time-fixed effects. Monetary values are discounted at 2010 prices. *Source*: Our elaboration on socioeconomic and sociodemographic data of the Italian Institute for Statistics, local government balance sheet data provided by the Italian Home Office, and data on earthquakes of the DBMI15 database of the Institute for Geophysics and Volcanology (Locati et al., 2016) [Color figure can beviewed at wileyonlinelibrary.com]

expenditure is sticky to decreasing unconditional grants, a result in line with the findings of Gennari and Messina (2014). Similarly, expenditure is less responsive to decreasing than to increasing earthquake-specific grants, although this asymmetric response is more pronounced than the response to unconditional transfers. The sum of the estimated parameters of earthquake-specific grants ($\hat{\alpha}_1$) and their asymmetry variable ($\hat{\alpha}_2$) is close to zero and suggests that a reduction in the transfers for earthquake recovery has negligible effects on spending levels.

In column 3, we report the results from the estimation of a 2SLS fixed-effects regression instrumenting general transfers and the relative asymmetry variable with the second lag of general transfers and the second lag of general transfers of neighboring municipalities (2-year spatial lag).[37] Diagnostic tests confirm that general transfers are endogenous and that the IV approach yields consistent estimates. We can see that the effect of general grants on spending levels is more remarkable than in column 1 and 2, and the coefficient of the asymmetric response to decreasing grants loses significance. These coefficients are very close to the estimates of Gennari and Messina (2014). Conversely, the estimated parameters of earthquake-specific grants and their asymmetry variable are very close to the coefficients reported in column 2. Overall, these results allow to conclude that there is evidence of flypaper effect for both types of grants. However, we find inconclusive evidence of an asymmetric response to increasing versus decreasing unconditional transfers (fiscal replacement), similarly to most previous studies but differently, for instance, from Levaggi and Zanola (2003), who testify a fiscal restraint type of asymmetry on regional health-care expenditure in Italy. Conversely, the fiscal replacement effect is remarkable for earthquake-specific matching grants, suggesting that public officials may exploit the occurrence of earthquakes to maintain higher spending levels. Moreover, local governments are apparently unable to fully exploit upper-level government transfers to increase expenditure when struck by an earthquake. This suggests a delay in the response to increasing

[37]To enhance the comparability of our results with those obtained by Gennari and Messina (2014), we repeat the estimation using the first and the second temporal lag of transfers, but differences are insignificant.

TABLE 4 Flypaper effect and asymmetric response to variations in transfers

	FE (1)	FE (2)	IV (3)
Earthquake-specific grants	0.280***	0.294***	0.254**
	(0.0790)	(0.0794)	(0.0830)
Asymmetry (eq.-specific grants)		−0.245***	−0.219***
		(0.0436)	(0.0471)
General grants	0.657***	0.746***	1.648**
	(0.0499)	(0.0445)	(0.588)
Asymmetry (general grants)		−0.336***	−0.0210
		(0.0286)	(0.673)
Income	0.0521***	0.0426***	0.0421***
	(0.00769)	(0.00689)	(0.00984)
Observations	119,816	111,825	103,681
Overall R^2	0.262	0.300	0.523
Within R^2	0.248	0.241	0.0188
Between R^2	0.268	0.320	0.648
Municipality fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Financial time-variant controls	Yes	Yes	Yes
Political controls	Yes	Yes	Yes
Sociodemographic controls	Yes	Yes	Yes
Hausman test			2,020.3***
Endogeneity test			21.23***

Note: It presents regression results for per capita local government expenditure. Models 1 and 2 are OLS regressions and Model 3 is a two-stage least square regression where general grants and the relative asymmetry variable are instrumented with the second lag of general grants and the second lag of general grants of neighboring municipalities (2-year spatial lag). Matching grants are earthquake-specific per capita transfers from central and regional governments allocated for recovery after the occurrence of an earthquake. Unconditional grants are general grants obtained as the difference between total grants and earthquake-specific grants. The two asymmetry variables measure decreases of each type of transfers between period $t-1$ and t. All models control for financial time-variant characteristics (per capita revenues from local taxation), political (center-right government, vote concentration, term limit, and years before elections), socioeconomic (average income and percent of low-income population) and sociodemographic factors (population density, percent of young, and percent of old population), municipality- and year fixed effects. Standard errors (in parentheses) are robust and clustered by municipality. Monetary values are discounted at 2010 prices.

***$p < .001$.

**$p < .01$

*$p < .05$.

grants, leading to an inefficient use of resources for disaster relief. We further address this aspect in the next Section 5.4.

5.4 | The north–south divide

5.4.1 | Timing of the response

Local governments may differ in the response to earthquake recovery measures. Several aspects, such as culture, history, and institutional quality, may affect this response. Barone and Mocetti (2014) argue that these differences influence economic outcomes after an earthquake. They compare two big earthquakes in Italy and show that the lower institutional quality in the South worsened after the shock and led to a lower economic growth (for a discussion on the regional divide in Italy, see, for instance, Felice, 2018; González, 2011). Following this evidence and inspired by the above findings on asymmetric and heterogeneous flypaper effects, we analyze how the response of local governments to earthquake shocks differs between northern and southern municipalities. The results from the estimation of the extended Equation (3) to include the interaction terms between grants and location are reported in Table 5.

As for unconditional grants, we do not observe a significantly different effect between northern and southern municipalities (in column 1, the coefficient of the interaction term between the South dummy and unconditional grants is not significant). Conversely, earthquake-specific grants show a significantly different effect between northern and southern municipalities. In the North, one additional euro of transfers for earthquake recovery raises expenditure by 1.43 euro, while in the South the effect is significantly lower (0.23 euro, i.e., the sum of the coefficient of earthquake-specific grants and the interaction term). Therefore, municipalities in the North seem to have a larger reaction to transfers for earthquake recovery, while expenditure in the South is much more sticky. Note that northern municipalities are generally less dependent on transfers, since personal income levels are higher, and their spending levels are lower, which may suggest a lower inertia to changes in transfers. As suggested by Vegh and Vuletin (2015), an increase in transfers has a larger effect on spending levels where the ratio between transfers and income is lower because transfers increase the municipality's income portfolio diversification and, thus, willingness to spend. Indeed, the flypaper effect is larger in the North than in the South since the correlation between earthquake-specific grants and personal income is lower in the former region (0.036 and 0.143, respectively).

The possible delay in the utilization of earthquake-related funds is worth of further analysis. The model in columns 2 and 3 includes the first and second lags of earthquake-specific grants and runs separate regressions for northern and southern municipalities. In the North, the inclusion of past matching grants in the regression reduces the estimated coefficient of current-period grants below one, while the coefficient of the first lag is significant and equal to 1.1, and the coefficient of the second lag is not significant. This suggests that northern local governments have at most 1-year delay in the reaction to additional resources from upper-level governments. Instead, in the South, the immediate response to matching grants is lower (0.132 vs. 0.679), and both the first and the second lags of grants are significant. Moreover, both lag coefficients are below one and lower than the estimated coefficients for the North, suggesting that a larger amount of financial resources received by local governments is not spent in the short run. This may indicate that municipalities in the South are affected by poorer institutional quality, which in turn may cause only partial or delayed recovery from earthquake damages and hinder local economic growth in the future. As suggested by Mauro (1995), the slower use of earthquake-related resources by municipalities in the South may be the consequence of higher levels of corruption.

5.4.2 | Spending composition and growth

To further explore possible inefficiencies in local government response to earthquake shocks, we analyze how disaster relief resources are allocated to different spending categories. In Table 6, we compare variations in the spending composition between municipalities in the North and in the South in the 5 years before and after the occurrence of an earthquake.[38,39] Before the shock, municipalities in the South spend on average 25.9% of the total budget on local services, which exceeds by 6.6% the budget allocated by municipalities in the North. Not

[38]The spending category "Other" includes local police, justice, culture, sports, and economic development, and accounts on average for less than 10% of the total budget.

[39]Table A.6 in appendix reports variations before and after the shock and between municipalities in the North and in the South and significance levels of t tests on mean differences.

TABLE 5 Impact of transfers on local government expenditure by macroregions

	Full sample (1)	North and center (2)	South (3)
Earthquake-specific grants	1.432**	0.679***	0.132**
	(0.487)	(0.132)	(0.0409)
South × earthquake-specific grants	−1.205*		
	(0.492)		
Earthquake-specific grants (t − 1)		1.103*	0.156***
		(0.506)	(0.0372)
Earthquake-specific grants (t− 2)		1.393	0.306***
		(0.768)	(0.0435)
General grants	0.646***	0.757***	0.786***
	(0.0572)	(0.0505)	(0.0392)
South × general grants	0.0714		
	(0.0614)		
Income	0.0521***	0.0450***	0.0727***
	(0.00761)	(0.00974)	(0.0208)
Observations	119,816	74,587	29,253
Overall R^2	0.270	0.393	0.483
Within R^2	0.258	0.219	0.408
Between R^2	0.275	0.456	0.525
Municipality fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Financial time-variant controls	Yes	Yes	Yes
Political controls	Yes	Yes	Yes
Sociodemographic controls	Yes	Yes	Yes

Note: It presents fixed-effects regression results for per capita local government expenditure. Model 1 uses the full sample of observations, Model 2 uses the subsample of municipalities located in the regions in the northern and central regions, and Model 3 uses the subsample of municipalities located in the southern regions (Abruzzo, Campania, Puglia, Basilicata, Calabria, and Sicily). Matching grants are earthquake-specific per capita transfers from central and regional governments, allocated for recovery after the occurrence of an earthquake. Unconditional grants are general transfers calculated as the difference between total grants and earthquake-specific grants. The two asymmetry variables measure decreases of each type of transfers between period t − 1 and t. South is a dummy variable equal to one for municipality located in the southern regions of Italy. All models control for financial time-variant characteristics (per capita revenues from local taxation), political (center-right government, vote concentration, term limit, and years before elections), socioeconomic (average income and percent of low-income population) and sociodemographic factors (population density, percent of young, and percent of old population), and year fixed effects. Standard errors (in parentheses) are robust and clustered by municipality. Monetary values are discounted at 2010 prices.

***$p < .001$

**$p < .01$.

*$p < .05$.

surprisingly, after the shock, the expenditure share of local services grows in both macro-regions since it includes expenditure on public infrastructures, water supply, and waste disposal. More precisely, municipalities in the north allocate 2.32% and 0.96% significantly more resources to local services and administration, respectively, while the budget share for the other spending categories significantly decreases, except for transport services. Instead, the share allocated to local services by southern municipalities increases by 5.1%, which goes to the detriment of

TABLE 6 Variation (in percent) of spending composition after an earthquake

	Before		After		
	North (1)	South (2)	Δ North (3)	Δ South (4)	Δ North – Δ South (5)
Local services	19.34	25.94	2.32***	5.10***	−2.78***
General administration	30.93	32.36	0.96*	−0.80	1.76**
Education	11.02	7.90	−0.84***	−0.32	−0.52
Social protection	11.82	6.72	−1.65***	−0.22	−1.42***
Transport services	13.44	12.25	0.38	−0.65*	1.03**
Other services	13.05	14.75	−0.94**	−3.04***	2.10***
Observations	911	951	3,587	2,572	

Note: It reports budget shares (columns 1 and 2) allocated to the main local government spending categories in the five years before a shock (with intensity ≥ 5) and average variations (in percent) within 5 years after the occurrence of the shock (columns 3 and 4). Southern municipalities include the regions of Abruzzo, Campania, Puglia, Basilicata, Calabria, and Sicily. Stars in columns 3 and 4 indicate significance levels of *t* tests on differences in means before and after the shock. Column 5 reports mean differences between variations in the North and the South, and stars indicate significance levels of *t* tests on mean differences.

***$p < .001$.

**$p < .01$.

*$p < .05$.

the budget share allocated to the other spending categories (a significant decrease for transport services and other services). Therefore, the main difference in the spending composition between northern and southern municipalities lies in the remarkable increase of funds for local services in the South, and a relatively more equal allocation of resources across spending categories in the North. While the response of local governments to earthquake shocks in northern municipalities encompasses all areas of government action, southern municipalities put their effort mainly in the enhancement of local services.

The heterogeneous response to earthquake shocks observed between the north and the south in terms of timing in the use of resources and their allocation points at the most efficient recovery from earthquake shocks. Therefore, we relate the availability and allocation of earthquake-specific resources to economic growth and compare treated and matched unaffected municipalities in the North and in the South.[40] We use personal income and mean housing prices as proxies for local economic growth since data on gross domestic product are not available at municipality level.[41] The trends of these variables are illustrated in Figure 5. Note that, in the north, personal income grows faster in struck municipalities than in unaffected municipalities in the first decade after an earthquake (Figure 5a). Conversely, in the South, the two groups of municipalities have identical income trends (Figure 5b). Similarly, housing prices (per square meter) in the South do not change significantly between struck and unaffected municipalities (Figure 5d). Instead, in the North, housing prices start to grow faster after 2 years in struck municipalities as compared to unaffected municipalities (Figure 5c). This evidence is even more pronounced if we limit the focus to earthquakes with intensity equal or greater than 6. It appears that the result is related to different responses to earthquake shocks between municipalities in the two macro-regions. Transfers from central and regional governments in the North (Figure 6a) grow after the occurrence of an earthquake, but converge to pre-earthquake levels after 5 years. Conversely, in the South, struck municipalities remain persistently more dependent on upper-tier government transfers for at least 10 years (see Figure 6b). Also, the budget share for local

[40]In this part of the analysis, we exclude municipalities from the region Abruzzo because the 2009 earthquake that affected this region is an outlying shock with strong damages and large financial windfall for reconstruction from upper-tier governments.

[41]See, for instance, Cheung, Wetherell, and Whitaker (2018) and Naoi, Seko, and Sumita (2009) for an examination of the effects of earthquakes in terms of house and land values.

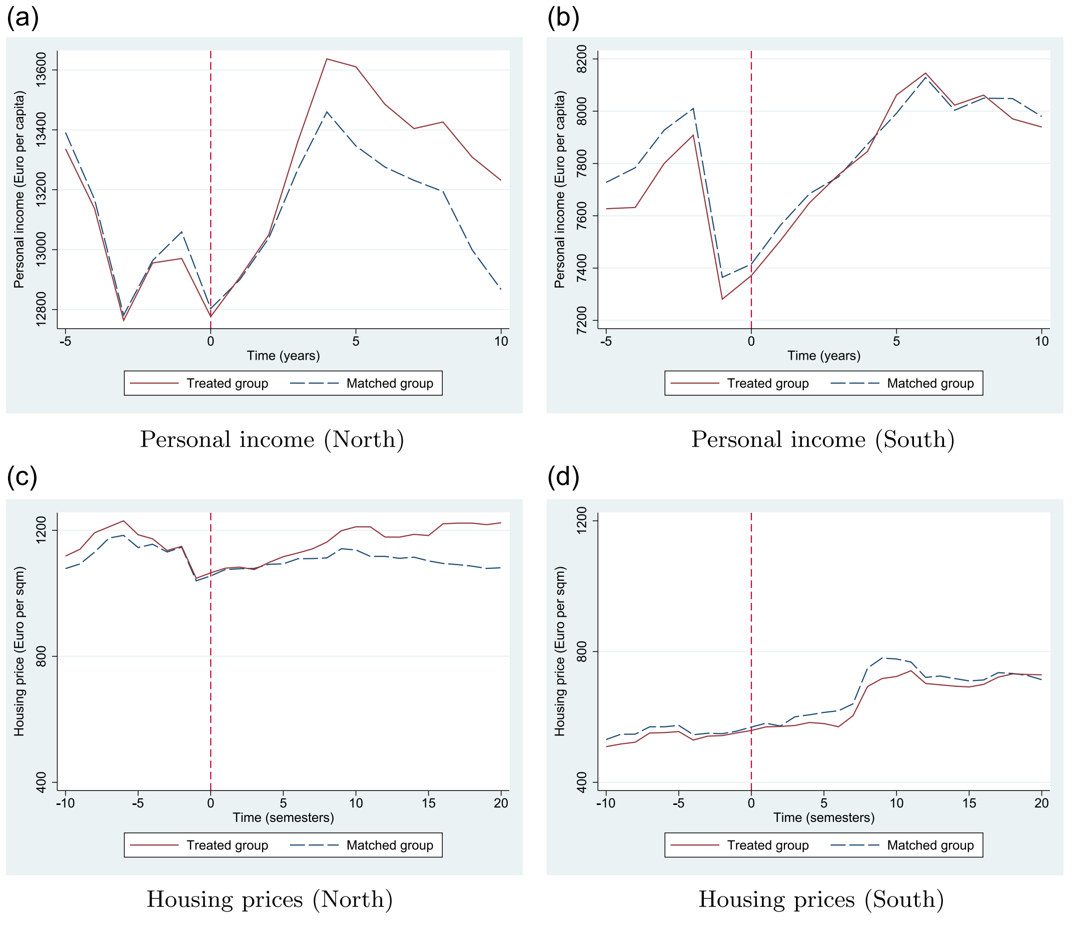

FIGURE 5 Economic outcomes after the occurrence of an earthquake. The graphs illustrate personal income ((a) for northern municipalities and (b) for southern municipalities) and mean housing prices per square meter ((c) for northern municipalities and (d) for southern municipalities) before and after the occurrence of an earthquake with intensity ≥ 5, which occurs at time zero. The top figures compare municipalities struck by an earthquake over the period 2000–2015 (treated group—red solid line) with matched unaffected municipalities (blue dashed line) identified with coarsened exact matching performed on average pretreatment characteristics of municipalities (institutional, socioeconomic, financial, and sociodemographic). The bottom figures compare municipalities struck by an earthquake over the period 2003–2015 with matched unaffected municipalities identified with coarsened exact matching performed on average pretreatment housing prices. Both groups include only municipalities with complete data for the respective period. Positive (negative) values on the *x*-axis indicate years (or semesters for housing prices) after (before) the treatment. Monetary values are discounted at 2010 prices.*Source:* Our elaboration on income data provided by the Italian Ministry of Economics and Finance, data on housing prices provided by the Real Estate Market Observatory of the Italian Revenue Agency, and data on earthquakes of the DBMI15 database of the Institute for Geophysics and Volcanology (Locati et al., 2016) [Color figure can beviewed at wileyonlinelibrary.com]

services in the South increases more in the treated group than in the counterfactual group after an earthquake (Figure 6d), but the gap between the two groups appears less prominent than in the North (Figure 6c).

This evidence obtained from the large data set of all Italian municipalities and earthquake events between 2000 and 2015, seems to confirm the heterogeneous effects between North and South found by Barone and Mocetti (2014) in their deep investigation of two Italian earthquakes. Even if a larger amount of resources for recovery is allocated to disaster areas in the South, these jurisdictions seem unable to exploit the financial windfall to recover

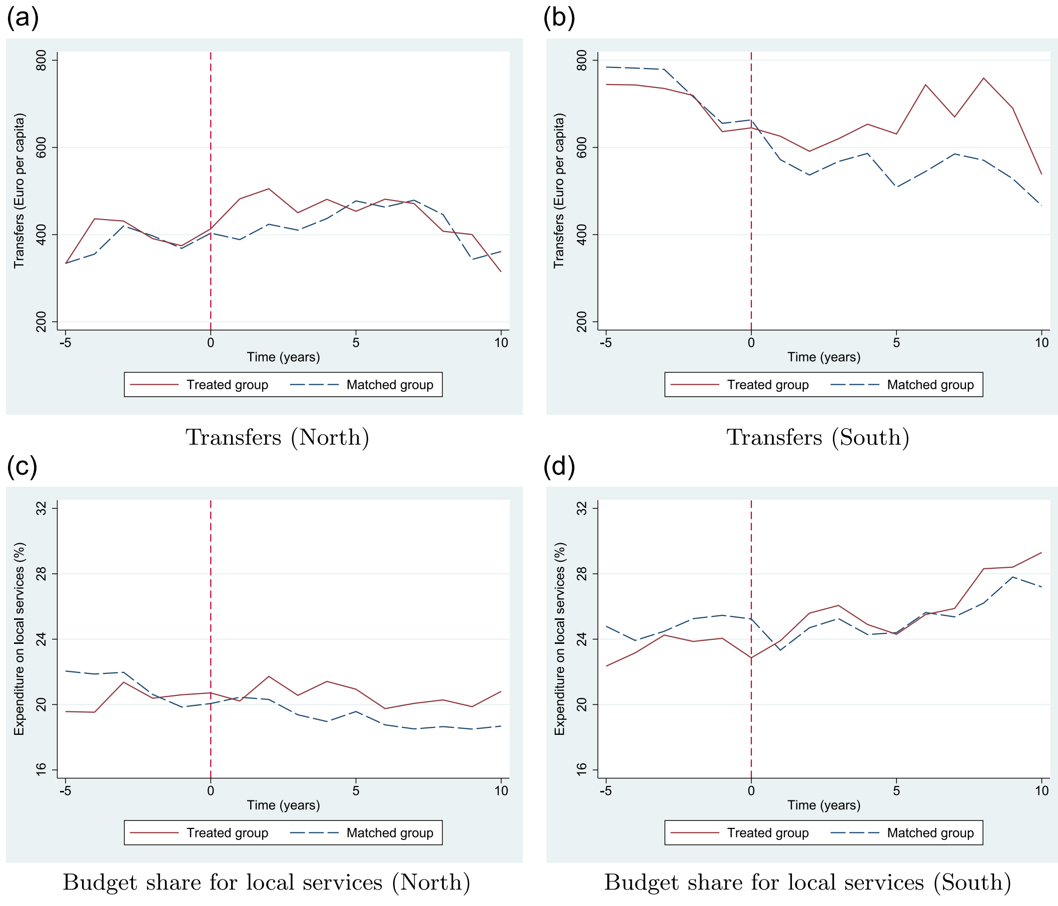

FIGURE 6 Variation of municipal financial characteristics after an earthquake. The graphs illustrate per capita transfers from central and regional governments ((a) for northern municipalities and (b) for southern municipalities) and the budget share allocated to local services ((c) for northern municipalities and (d) for southern municipalities) before and after the occurrence of an earthquake with intensity ≥ 5, which occurs at time zero. Each graph compares municipalities struck by an earthquake over the period 2000–2015 (treated group—red solid line) with matched unaffected municipalities (blue dashed line) identified with coarsened exact matching performed on average pretreatment characteristics of municipalities (institutional, socioeconomic, financial, and sociodemographic). Both groups include only municipalities with complete data for the period 2000–2015. Positive (negative) values on the *x*-axis indicate years after (before) the treatment. Monetary values are discounted at 2010 prices. *Source:* Our elaboration on local government balance sheet data provided by the Italian Home Office, and data on earthquakes of the DBMI15 database of the Institute for Geophysics and Volcanology (Locati et al., 2016) [Color figure can beviewed at wileyonlinelibrary.com]

from damages and improve economic growth. Conversely, local governments in the north appear more efficient in exploiting transfers from upper-level governments to expand expenditure and recover from damages. This translates into new infrastructure and the replacement of obsolete technologies destroyed or damaged by the earthquake, which allows to foster local economic development and to accelerate growth. Likely, the allocation of resources among spending categories in the north speeds up recovery and fosters local economic growth. The higher increase in the expenditure share for local services in the South could suggest that resources are not used efficiently or favor corruption. Indeed, although local services represents the spending category mostly affected by earthquakes (urban road maintenance and the maintenance/construction of public buildings), the construction industry is also well exposed to corruption scandals.

The interpretation of our results finds some support in theories that explain the backwardness of the south of Italy in the last century. The lower institutional quality compared to the North is a pre-existing characteristic of the area that affects efficiency in the response to earthquakes. The South is historically characterized by rent-seeking behavior, reluctance to change, lack of entrepreneurship, and a weak socio-institutional structure that hinders public intervention to reduce the North–South gap (Capello, 2016). Whether it is because of the low efficiency of public institutions or the lack of private initiative, these characteristics make it difficult to exploit the opportunity offered by earthquakes and earthquake-specific grants to reconstruct and reorganize local growth and development. Hence, the slow recovery is likely the result of upper-tier government intervention rather than local economic resilience (Xiao, 2011).

6 | CONCLUDING REMARKS

Local governments differ in the response to economic and social damages caused by natural disasters (earthquakes), in terms of spending behavior and the use of grants from upper tiers. Earthquake-related grants (matching grants) may also differ from other types of grants (mostly unconditional) in terms of stimulatory power, and expenditure may differ in the response to increasing and decreasing grants, leading to asymmetric and heterogeneous reactions (different flypaper effects). Since natural disasters are particularly good examples of exogenous shocks to economies, the exogenous nature of earthquakes allows us to better identify any flypaper effect. We explore these aspects using municipality data and all earthquake shocks from a country largely exposed to seismic events—Italy—between 2000 and 2015.

We find evidence of increasing expenditure for about 11–12 years after a shock, before regressing to pre-earthquake levels. Over the whole period, affected municipalities spend 962 euro per individual more than not affected municipalities, and transfers from central and regional governments exceed expenditure by about 240 euro per individual. The average impact of both earthquake-specific and unconditional grants on expenditure is much larger than the response to income, suggesting the presence of a flypaper effect. However, we find evidence of an asymmetric response to decreasing grants (i.e., a fiscal replacement effect) only for earthquake-specific grants, suggesting that public officials tend to maintain higher spending levels after the occurrence of an earthquake.

The impact of matching grants is remarkably heterogeneous across the country. In the North, municipalities are more sensitive to variations in transfers (one additional euro raises expenditure by 1.43 euro), while southern municipalities react to the drop of grants showing inertia in expenditure levels (0.23 euro response). Likely, the lower dependency on upper-tier government transfers by the North allows for a larger effect on municipality income portfolio diversification and, therefore, spending levels as compared to the South (Vegh & Vuletin, 2015).

Although earthquake shocks provide the opportunity to reorganize economic activities and foster urban development (Xu & Wang, 2019), this opportunity is channeled through the efficient use of resources. Our evidence suggests a more efficient recovery in northern municipalities which allows both personal income and housing prices to grow faster than if no earthquake would have occurred, as suggested by Barone and Mocetti (2014). These findings are consistent with Bondonio and Greenbaum (2018) showing that more socio-economically disadvantaged areas (the South) are less able to exploit opportunities to recover. Indeed, while the response of northern municipalities encompasses all areas of government action, southern municipalities put their effort mainly in the enhancement of local services. Therefore, evidence from northern municipalities points at a possible explanation in accordance with the recent finding by Allers and Vermeulen (2016), showing that additional grants are capitalized into house values rather than in rent taking by bureaucrats or politicians. Conversely, the extraction of rent from uninformed voters by self-interested politicians (Brollo, Nannicini, Perotti, & Tabellini, 2013; Persson & Tabellini, 2000) could represent a more valid explanation for southern regions. Here, the spending category mostly affected by earthquake damages (local services) attracts the largest part of additional grants, fostering exposure to corruption scandals within the construction industry (Galletta, 2017).

To conclude, the role of upper-level governments is crucial in disaster relief but the quality of the response of local governments affects economic outcomes. There is scope for an improved monitoring system on how local governments employ disaster relief resources to recover quickly and efficiently. Future research should investigate more in detail factors affecting efficient recovery to identifying best practices and provide guidance for policy-makers.

ACKNOWLEDGMENTS

We are grateful to Massimo Filippini and Fabrizio Mazzonna for constructive suggestions and useful advice for further improvement of the preliminary analysis. Also, we thank Rosella Levaggi and other participants to the DREAMT Workshop 2019 in Pavia, and to the XXX SIEP Conference in Padova for numerous helpful comments. Finally, we are indebted to two anonymous reviewers and the editor for very constructive comments during the revision process. Any mistakes are the fault of the authors only.

ORCID

Giuliano Masiero http://orcid.org/0000-0001-5480-0829

REFERENCES

Allers, M. A., & Vermeulen, W. (2016). Capitalization of equalizing grants and the flypaper effect. *Regional Science and Urban Economics*, *58*, 115–129.

Bailey, S. J., & Connolly, S. (1998). The flypaper effect: Identifying areas for further research. *Public Choice*, *95*(3), 335–361.

Barone, G., & Mocetti, S. (2014). Natural disasters, growth and institutions: A tale of two earthquakes. *Journal of Urban Economics*, *84*, 52–66.

Bevan, D., & Cook, S. (2015). *Public expenditure following disasters* (Policy Research Working Paper No. 7355). The World Bank: Washington, DC.

Blackwell, M., Iacus, S., King, G., & Porro, G. (2009). cem: Coarsened exact matching in Stata. *The Stata Journal*, *9*(4), 524–546.

Bondonio, D., & Greenbaum, R. T. (2018). Natural disasters and relief assistance: Empirical evidence on the resilience of U.S. counties using dynamic propensity score matching. *Journal of Regional Science*, *58*(3), 659–680.

Boustan, L. P., Kahn, M. E., Rhode, P. W., & Yanguas, M. L. (2017). *The effect of natural disasters on economic activity in US counties: A century of data* (NBER Working Paper 23410). National Bureau of Economic Research: Cambridge, MA.

Brollo, F., Nannicini, T., Perotti, R., & Tabellini, G. (2013). The political resource curse. *American Economic Review*, *103*(5), 1759–1796.

Bui, A. T., Dungey, M., Nguyen, C. V., & Pham, T. P. (2014). The impact of natural disasters on household income, expenditure, poverty and inequality: Evidence from Vietnam. *Applied Economics*, *46*(15), 1751–1766.

Capello, R. (2016). What makes Southern Italy still lagging behind? A diachronic perspective of theories and approaches. *European Planning Studies*, *24*(4), 668–686.

Cavallo, E., Galiani, S., Noy, I., & Pantano, J. (2013). Catastrophic natural disasters and economic growth. *Review of Economics and Statistics*, *95*(5), 1549–1561.

Cavallo, E., & Noy, I. (2010). *The economics of natural disasters: A survey* (IDB Working Paper No. 124). Department of Research and Chief Economist, Inter-American Development Bank: Washington, DC.

Cheung, R., Wetherell, D., & Whitaker, S. (2018). Induced earthquakes and housing markets: Evidence from Oklahoma. *Regional Science and Urban Economics*, *69*, 153–166.

Cipollone, P., & Rosolia, A. (2007). Social interactions in high school: Lessons from an earthquake. *American Economic Review*, *97*(3), 948–965.

Davis, D. R., & Weinstein, D. E. (2002). Bones, bombs, and break points: The geography of economic activity. *American Economic Review*, *92*(5), 1269–1289.

Felice, E. (2018). The socio-institutional divide: Explaining Italy's long-term regional differences. *The Journal of Interdisciplinary History*, *49*(01), 43–70.

Gallagher, J. (2014). Learning about an infrequent event: Evidence from flood insurance take-up in the United States. *American Economic Journal*, *6*(3), 206–233.

Galletta, S. (2017). Law enforcement, municipal budgets and spillover effects: Evidence from a quasi-experiment in Italy. *Journal of Urban Economics*, *101*, 90–105.

Gamkhar, S., & Oates, W. (1996). Asymmetries in the response to increases and decreases in intergovernmental grants: Some empirical findings. *National Tax Journal*, *49*(4), 501–512.

Gennari, E., & Messina, G. (2014). How sticky are local expenditures in Italy? Assessing the relevance of the flypaper effect through municipal data. *International Tax and Public Finance*, *21*(2), 324–344.

Di Giacomo, M. (2014). *I costi dei terremoti in Italia* (Report No. 340). Centro Studi Consiglio Nazionale Ingegneri: Rome, Italy.

González, S. (2011). The north/south divide in Italy and England: Discursive construction of regional inequality. *European Urban and Regional Studies*, *18*(1), 62–76.

Gramlich, E. M. (1977). Intergovernmental grants: A review of the empirical literature. In W. E. Oates (Ed.), *The political economy of fiscal federalism* (pp. 219–239). Lexington, MA: Lexington Books.

Gramlich, E. M. (1987). Federalism and federal deficit reduction. *National Tax Journal*, *40*(3), 299–313.

Guha-Sapir, D., Below, R., & Hoyois, P. (2017). *EM-DAT: The CRED/OFDA International Disaster Database* (www.emdat.be) (Data source). Université Catholique de Louvain: Brussels, Belgium.

Hamilton, B. W. (1983). The flypaper effect and other anomalies. *Journal of Public Economics*, *22*(3), 347–361.

Healy, A., & Malhotra, N. (2009). Myopic voters and natural disaster policy. *American Political Science Review*, *103*(03), 387–406.

Hornbeck, R., & Keniston, D. (2017). Creative destruction: Barriers to urban growth and the Great Boston Fire of 1872. *American Economic Review*, *107*(6), 1365–1398.

Horwich, G. (2000). Economic lessons of the Kobe earthquake. *Economic Development and Cultural Change*, *48*(3), 521–542.

Italian Institute for Statistics. (2017). *I bilanci di comuni, province e aree metropolitane* (Report 2015). Italian Institute for Statistics (ISTAT): Rome, Italy. Retrieved from https://www4.istat.it/it/files/2017/11/Report_bilancixomuni_province_aree_metropolitane.pdf?title=Bilanci+enti+locali+-+03%2Fnov%2F2017+-+Testo+integrale+e+nota+metodologica.pdf

Kahn, M. E. (2005). The death toll from natural disasters: The role of income, geography, and institutions. *Review of Economics and Statistics*, *87*(2), 271–284.

Levaggi, R., & Zanola, R. (2003). Flypaper effect and sluggishness: Evidence from regional health expenditure in Italy. *International Tax and Public Finance*, *10*(5), 535–547.

Locati, M., Camassi, R., Rovida, A., Ercolani, E., Bernardini, F., Castelli, V., … Rocchetti, E. (2016). *DBMI15, the 2015 version of the italian macroseismic database* (Data source). Istituto Nazionale di Geofisica e Vulcanologia: Rome, Italy.

Lundqvist, H. (2015). Granting public or private consumption? Effects of grants on local public spending and income taxes. *International Tax and Public Finance*, *22*(1), 41–72.

Mauro, P. (1995). Corruption and growth. *The Quarterly Journal of Economics*, *110*(3), 681–712.

Melecky, M., & Raddatz, C. (2011). *How do governments respond after catastrophes? Natural-disaster shocks and the fiscal stance* (Policy Research Working Paper No. 5564). The World Bank: Washington, DC.

Naoi, M., Seko, M., & Sumita, K. (2009). Earthquake risk and housing prices in Japan: Evidence before and after massive earthquakes. *Regional Science and Urban Economics*, *39*(6), 658–669.

Noy, I., & Nualsri, A. (2011). Fiscal storms: Public spending and revenues in the aftermath of natural disasters. *Environment and Development Economics*, *16*(1), 113–128.

Persson, T., & Tabellini, G. E. (2000). *Political economics: Explaining economic policy*. Cambridge, MA: MIT press.

Revelli, F. (2006). Performance rating and yardstick competition in social service provision. *Journal of Public Economics*, *90*(3), 459–475.

Rovida, A., Locati, M., Camassi, R., Lolli, B., & Gasperini, P. (2016). *CPTI15, the 2015 version of the parametric catalogue of italian earthquakes* (Data source). Istituto Nazionale di Geofisica e Vulcanologia: Rome, Italy.

Skidmore, M., & Toya, H. (2002). Do natural disasters promote long-run growth? *Economic Inquiry*, *40*(4), 664–687.

Skoufias, E. (2003). Economic crises and natural disasters: Coping strategies and policy implications. *World Development*, *31*(7), 1087–1102.

Strömberg, D. (2007). Natural disasters, economic development, and humanitarian aid. *Journal of Economic Perspectives*, *21*(3), 199–222.

Vegh, C. A., & Vuletin, G. (2015). Unsticking the flypaper effect in an uncertain world. *Journal of Public Economics*, *131*, 142–155.

Xiao, Y. (2011). Local economic impacts of natural disasters. *Journal of Regional Science*, *51*(4), 804–820.

Xu, H., & Wang, S. (2019). Urban redevelopment and residential location choice: Evidence from a major earthquake in Japan. *Journal of Regional Science*, 1–33. https://doi.org/10.1111/jors.12424

How to cite this article: Masiero G, Santarossa M. Earthquakes, grants, and public expenditure: How municipalities respond to natural disasters. *J Regional Sci*. 2020;60:481–516. https://doi.org/10.1111/jors.12462

APPENDIX A

A.1 Matching approach

To construct a counterfactual group of municipalities, we apply a matching procedure starting from the full sample of 1,129 municipalities struck at least once by an earthquake over the period 2000–2015. We exclude 252 municipalities affected by an earthquake in year 2000 because we lack data on pre-treatment characteristics before that year. Moreover, we keep only municipalities with complete data for the period 2000–2015. The resulting subsample of treated municipalities is composed of 743 units.

To build an equal-sized control group of municipalities not struck by earthquakes, we use the remaining 5,339 municipalities with complete data for the period 2000–2015. Moreover, we exclude 1,001 municipalities that share part of the border with struck municipalities to abstract from possible spillover effects of earthquake occurrence. Therefore, our final donor pool is composed of 4,338 unaffected municipalities. Since geographical proximity may be not sufficient to build a control group with similar institutional characteristics in the pre-treatment period, especially if contiguous municipalities are located in other regions, we build a control based on institutional proximity, intended as similarity in institutional factors.[42] To this aim, we force the matching with municipalities in the same region. This procedure guarantees that matched municipalities are subject to the same institutional setting and have little geographical discontinuity. We also match pre-treatment average transfers from the central government and from the regions, personal income, population size (less or greater than 15,000 people), the budget share allocated to local services, the propensity to face an earthquake (using seismic zones, see Section 2.1) and historical earthquake experience. To measure historical earthquake experience, we define the index $EQL_{i,2000} = \sum_{t=1000}^{1999} (EQ_{i,t}/(2000 - t))$. This is the sum of earthquakes with intensity ≥ 5 occurred before 2000 weighted by the inverse of the number of years passed since the occurrence of the shocks. Due to data limitations, the index accounts only for earthquakes occurred since 1000 AD.

To perform the matching we use the coarsened exact matching (CEM) applied with the *cem* command in Stata 13 developed by Blackwell, Iacus, King, and Porro (2009). The advantage of CEM compared to other matching procedures is that the matching imbalance is lower, model dependence and bias in post-matching estimation are reduced, and efficiency is improved. Since the treatment occurs at different points in time for different municipalities, we repeat the matching procedure for each period between 2001 and 2015 by allowing replacement of matched untreated municipalities. We do not impose any custom restrictions on the cut-points that define the coarsening and use the standards. Since we want exact matching to occur on the region, we repeat the CEM algorithm for each regional subsample.

CEM was able to match 347 municipalities out of the 743 treated municipalities. Indeed, *t* tests on mean differences show that matching characteristics and per capita local government expenditure are not significantly different between the two groups before the occurrence of an earthquake (see columns 1 and 2 of Table A.1 below). Conversely, average characteristics of the universe of municipalities (column 3) differ significantly from the characteristics of the treated group, except for budget share allocated to local services.

[42]Cipollone and Rosolia (2007) construct a control group of municipalities using geographical proximity as a proxy for the similarity of treated and controlled municipalities to analyze social interactions in high school after an earthquake. While the schooling system is mostly centralized, local institutional aspects related to spending levels and funding sources may be quite heterogeneous, especially across regions.

TABLE A.1 Balancing properties resulting from the matching approach

	Treated (1)	Matched (2)	All unaffected (3)
Expenditure p/c	1,199.9	1,207.4	1,509.0***
Transfers p/c	515.4	525.2	549.4***
Income	10,639.8	10,676.5	11,803.6***
Population	5,158.1	4,892.4	6,254.9***
Local services	21.96	22.52	21.74
Seismic zone 1	0.0994	0.0994	0.0581***
Seismic zone 2	0.519	0.519	0.187***
Seismic zone 3	0.306	0.306	0.191***
EQL_{2000}	0.125	0.118	0.0278***
Observations	3,458	3,458	84,967

Note: It reports mean characteristics of 347 municipalities struck by an earthquake with intensity ≥ 5 (column 1) and their matched unaffected municipalities (column 2) before the occurrence of an earthquake, and of the universe of unaffected municipalities for the period 2000–2015 (column 3). Except for expenditure, the reported characteristics are those used to build the group of matched municipalities (institutional proximity is omitted because of exact matching on that characteristic—see Section A.1). Stars in column 3 indicate significance levels of *t* tests on mean differences between column 1 and 3. *t* Tests on mean differences between column 1 and 2 reveal not significant differences for all characteristics. Monetary values are discounted at 2010 prices.
***$p < .001$.

TABLE A.2 Impact of earthquakes on local government expenditure using alternative model specifications

	Excluding covariates		Spatial correlation	
	FE (1)	FE (AR1) (2)	FE (3)	FE (AR1) (4)
EQ_t	0.00000850	0.00723	0.0193*	0.0190**
	(0.00971)	(0.00797)	(0.00861)	(0.00736)
EQ_{t-1}	0.0582***	0.0566***	0.0667***	0.0609***
	(0.0112)	(0.00889)	(0.00977)	(0.00808)
$EQ_{t-d} \times Dist$	0.0354***	0.0190***	0.0302***	0.0164***
	(0.00495)	(0.00294)	(0.00397)	(0.00254)
$EQ_{t-d} \times Dist^2$	−0.00592***	−0.00345***	−0.00451***	−0.00257***
	(0.000756)	(0.000459)	(0.000616)	(0.000404)
$EQ_{t-d} \times Dist^3$	0.000231***	0.000141***	0.000161***	0.0000947***
	(0.0000303)	(0.0000189)	(0.0000251)	(0.0000170)
$EQ_{-i,t}$			0.00642	0.00609
			(0.00499)	(0.00443)
$EQ_{-i,t-1}$			0.0187***	0.0173***
			(0.00498)	(0.00438)
Observations	119,816	119,102	119,816	119,102
Overall R^2	0.178	0.761	0.382	0.760

(Continues)

TABLE A.2 (Continued)

	Excluding covariates		Spatial correlation	
	FE	FE (AR1)	FE	FE (AR1)
	(1)	(2)	(3)	(4)
Within R^2	0.518	0.616	0.599	0.663
Between R^2	0.0128	0.994	0.278	0.824
Municipality fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Financial time-variant controls	No	No	Yes	Yes
Political controls	No	No	Yes	Yes
Socioeconomic controls	No	No	Yes	Yes
Sociodemographic controls	No	No	Yes	Yes

Note: It presents fixed effects regression results for the log of per capita local government expenditure. In columns 1 and 2, we include only the variables measuring earthquake occurrence. In columns 3 and 4, we control for the full set of covariates and further account for spatial correlation of earthquake occurrence. EQ_t and EQ_{t-1} are dummy variables equal to one if there has been an earthquake in the current year and in the previous year, respectively, and zero otherwise. EQ_{t-d} is a dummy variable equal to one measuring the occurrence of the latest earthquake within the last 15 years, and zero otherwise. $1 < d \leq 15$ measures the temporal distance from the latest earthquake. $EQ_{-i,t}$ and $EQ_{-i,t-1}$ are dummy variables equal to one if there has been an earthquake in a neighboring municipality in the current year and in the previous year, respectively, and zero otherwise. All models control for year fixed effects. Models 3 and 4 also control for financial time-variant (logs of per capita transfers from the central and regional governments and revenues from local taxation), political (center-right government, vote concentration, term limit, years before elections), socioeconomic (average income and percent of low-income population) and sociodemographic factors (population density, percent of young and percent of old population). Models 2 and 4 further control for the lag of the dependent variable. Standard errors (in parentheses) are robust and clustered by municipality. Monetary values are discounted at 2010 prices.

***$p < .001$

**$p < .01$.

*$p < .05$.

TABLE A.3 Impact of earthquakes on local government expenditure using the matching sample

	OLS	RE	FE	FE (AR1)
	(1)	(2)	(3)	(4)
EQ_t	0.0443	0.0261	0.0248	0.0338**
	(0.0236)	(0.0148)	(0.0151)	(0.0129)
EQ_{t-1}	0.113***	0.0883***	0.0868***	0.0804***
	(0.0271)	(0.0195)	(0.0198)	(0.0155)
$EQ_{t-d} \times Dist$	0.0399**	0.0280**	0.0273**	0.0129*
	(0.0132)	(0.00959)	(0.00970)	(0.00533)
$EQ_{t-d} \times Dist^2$	−0.00558**	−0.00422**	−0.00414*	−0.00191*
	(0.00206)	(0.00162)	(0.00162)	(0.000905)
$EQ_{t-d} \times Dist^3$	0.000175*	0.000155*	0.000153*	0.0000687
	(0.0000891)	(0.0000727)	(0.0000727)	(0.0000420)
Observations	11,104	11,104	11,104	11,104
Overall R^2	0.350	0.349	0.221	0.744

(Continues)

TABLE A.3 (Continued)

	OLS (1)	RE (2)	FE (3)	FE (AR1) (4)
Within R^2		0.514	0.514	0.628
Between R^2		0.227	0.00631	0.992
Region fixed effects	Yes	Yes	No	No
Year fixed effects	Yes	Yes	Yes	Yes

Note: It presents regression results for the log of per capita local government expenditure using a sample composed of 347 treated and 347 matched municipalities identified with coarsened exact matching (*cem* command in Stata 13) on average pretreatment institutional, sociodemographic, and environmental characteristics. Model 1 is an OLS regression, Model 2 a random-effects regression, and Models 3 and 4 are fixed effects regressions. EQ_t and EQ_{t-1} are dummy variables equal to one if there has been an earthquake in the current year and in the previous year, respectively, and zero otherwise. EQ_{t-d} is a dummy variable equal to one measuring the occurrence of the latest earthquake within the last 15 years, and zero otherwise. $1 < d \leq 15$ measures the temporal distance from the latest earthquake. All models control for year-fixed effects. Models 1 and 2 further control for region fixed effects, which are time-invariant, and Model 4 for the lag of the dependent variable. Standard errors (in parentheses) are robust and clustered by municipality. Monetary values are discounted at 2010 prices.

***$p < .001$.

**$p < .01$.

*$p < 0.05$.

TABLE A.4 Sensitivity analysis of the impact of earthquakes on local government expenditure

	Single earthquake		No earthquakes 1988–1999		No earthquakes 2010–2015	
	FE (1)	FE (AR1) (2)	FE (3)	FE (AR1) (4)	FE (5)	FE (AR1) (6)
EQ_t	0.0164	0.0168*	0.0554***	0.0450***	0.0221*	0.0186*
	(0.00891)	(0.00802)	(0.0113)	(0.00965)	(0.00917)	(0.00794)
EQ_{t-1}	0.0659***	0.0627***	0.110***	0.0933***	0.0710***	0.0620***
	(0.0105)	(0.00882)	(0.0137)	(0.0111)	(0.0106)	(0.00875)
$EQ_{t-d} \times Dist$	0.0308***	0.0168***	0.0420***	0.0248***	0.0317***	0.0173***
	(0.00405)	(0.00259)	(0.00649)	(0.00423)	(0.00416)	(0.00266)
$EQ_{t-d} \times Dist^2$	−0.00465***	−0.00268***	−0.00526***	−0.00306***	−0.00485***	−0.00279***
	(0.000629)	(0.000412)	(0.00102)	(0.000685)	(0.000645)	(0.000423)
$EQ_{t-d} \times Dist^3$	0.000168***	0.000100***	0.000181***	0.000105***	0.000177***	0.000106***
	(0.0000257)	(0.0000173)	(0.0000441)	(0.0000307)	(0.0000262)	(0.0000177)
Observations	118,176	117,470	93,314	92,782	117,882	117,181
Struck municipalities	1,025	1,025	819	819	1,004	1,004
Overall R^2	0.384	0.760	0.362	0.732	0.384	0.761
Within R^2	0.599	0.663	0.607	0.665	0.599	0.663
Between R^2	0.281	0.824	0.251	0.777	0.281	0.826
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

(Continues)

TABLE A.4 (Continued)

	Single earthquake		No earthquakes 1988–1999		No earthquakes 2010–2015	
	FE (1)	FE (AR1) (2)	FE (3)	FE (AR1) (4)	FE (5)	FE (AR1) (6)
Financial time-variant controls	Yes	Yes	Yes	Yes	Yes	Yes
Political controls	Yes	Yes	Yes	Yes	Yes	Yes
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes	Yes
Sociodemographic controls	Yes	Yes	Yes	Yes	Yes	Yes

Note: It presents fixed-effects regression results for the log of per capita local government expenditure. In columns 1 and 2, municipalities that faced more than one earthquake between 2000 and 2015 are excluded. In columns 3 and 4, municipalities struck in the 12 years before 2000 are excluded. In columns 5 and 6, municipalities struck after 2009 are excluded. EQ_t and EQ_{t-1} are dummy variables equal to one if there has been an earthquake in the current year and in the previous year, respectively, and zero otherwise. EQ_{t-d} is a dummy variable equal to one measuring the occurrence of the latest earthquake within the last 15 years, and zero otherwise. $1 < d \le 15$ measures the temporal distance from the latest earthquake. All models control for financial time-variant (logs of per capita transfers from the central and regional governments and revenues from local taxation), political (center-right government, vote concentration, term limit, and years before elections), socioeconomic (average income and percent of low-income population) and sociodemographic factors (population density, percent of young and percent of old population), and year-fixed effects. Models 2, 4, and 6 further control for the lag of the dependent variable. Standard errors (in parentheses) are robust and clustered by municipality. Monetary values are discounted at 2010 prices.

***$p < .001$.

**$p < .01$.

*$p < .05$.

TABLE A.5 Impact of earthquakes on local government expenditure using different intensity-based earthquake occurrence measures

	Intensity-based measures		Magnitude-based measures		
	$I \ge 6$ (1)	$I \ge 7$ (2)	$D \le 10$ km (3)	$D \le 20$ km (4)	$D \le 30$ km (5)
EQ_t	0.0554**	0.156**	0.0182*	0.0133**	0.0101**
	(0.0203)	(0.0562)	(0.00914)	(0.00485)	(0.00389)
EQ_{t-1}	0.250***	0.550***	0.0602***	0.0427***	0.0328***
	(0.0262)	(0.0717)	(0.0107)	(0.00549)	(0.00422)
$EQ_{t-d} \times Dist$	0.120***	0.262***	0.0231***	0.0168***	0.00739*
	(0.0102)	(0.0294)	(0.00694)	(0.00384)	(0.00307)
$EQ_{t-d} \times Dist^2$	−0.0165***	−0.0343***	−0.00393**	−0.00301***	−0.000955
	(0.00159)	(0.00425)	(0.00129)	(0.000739)	(0.000611)
$EQ_{t-d} \times Dist^3$	0.000565***	0.00112***	0.000160*	0.000134***	0.0000271
	(0.0000636)	(0.000165)	(0.0000655)	(0.0000390)	(0.0000333)
Observations	119,816	119,816	119,816	119,816	119,816
Overall R^2	0.389	0.396	0.391	0.391	0.392

(Continues)

TABLE A.5 (Continued)

	Intensity-based measures		Magnitude-based measures		
	$I \geq 6$	$I \geq 7$	$D \leq 10$ km	$D \leq 20$ km	$D \leq 30$ km
	(1)	(2)	(3)	(4)	(5)
Within R^2	0.603	0.602	0.598	0.598	0.598
Between R^2	0.285	0.294	0.290	0.290	0.290
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Financial time-variant controls	Yes	Yes	Yes	Yes	Yes
Political controls	Yes	Yes	Yes	Yes	Yes
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes
Sociodemographic controls	Yes	Yes	Yes	Yes	Yes

Note: It presents fixed-effects regression results for the log of per capita local government expenditure using earthquakes with intensity ≥ 6 (column 1) and ≥7 (column 2), and magnitude ≥ 4 (columns 3–5) for the identification of treated municipalities. In columns 3, 4, and 5, treatment is assigned if the centroid of a municipality is located within 10, 20, and 30 km, respectively. EQ_t and EQ_{t-1} are dummy variables equal to one if there has been an earthquake in the current year and in the previous year, respectively, and zero otherwise. EQ_{t-d} is a dummy variable equal to one measuring the occurrence of the latest earthquake within the last 15 years, and zero otherwise. $1 < d \leq 15$ measures the temporal distance from the latest earthquake. All models control for financial time-variant (logs of per capita transfers from the central and regional governments and revenues from local taxation), political (center-right government, vote concentration, term limit, and years before elections), socioeconomic (average income and percent of low-income population) and sociodemographic factors (population density, percent of young, and percent of old population), and year-fixed effects. Models 2 and 4 further control for the lag of the dependent variable. Standard errors (in parentheses) are robust and clustered by municipality. Monetary values are discounted at 2010 prices.

***$p < .001$.

**$p < .01$.

*$p < .05$.

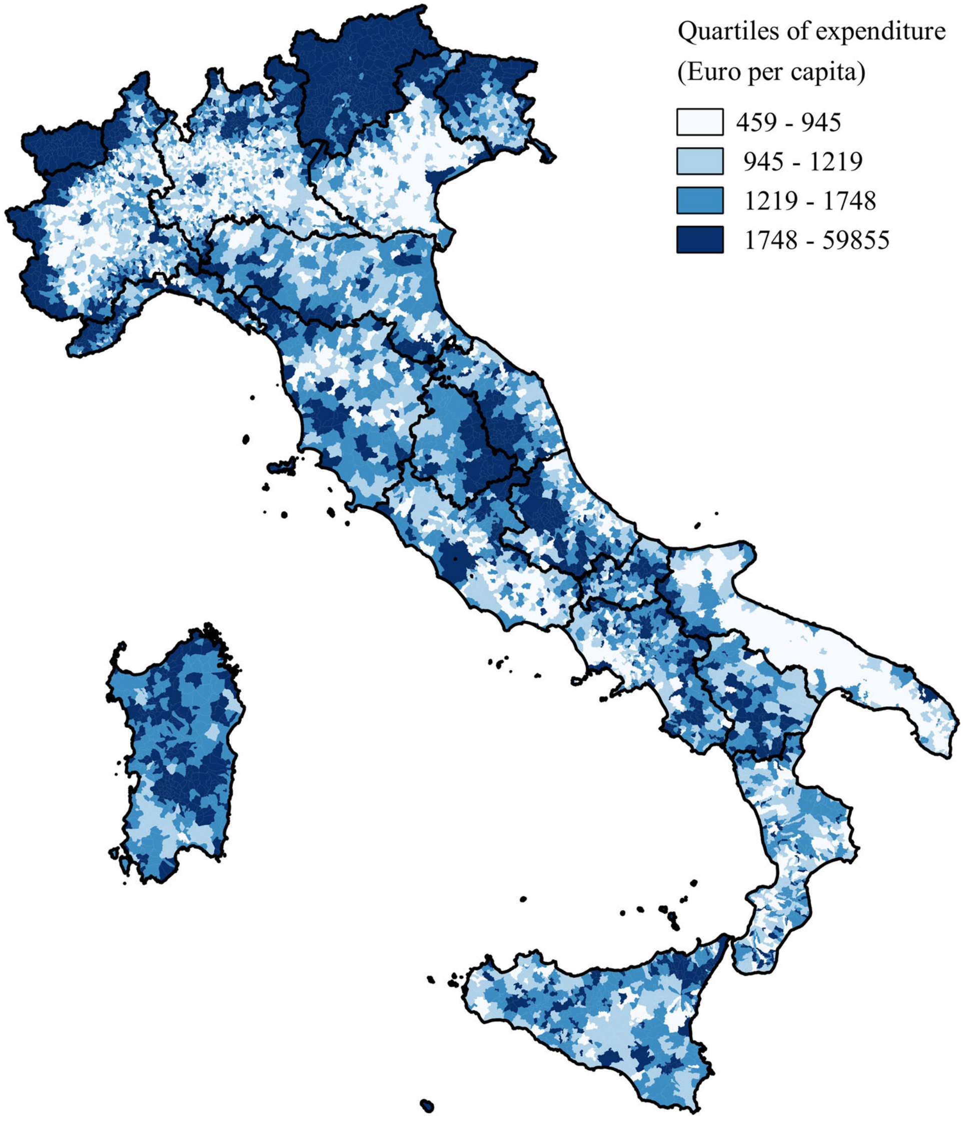

FIGURE A.1 Local government expenditure (2000–2015). The map shows the average per capita local government expenditure in euro by municipality for a 16-year period (2000–2015). The darker the color, the higher the expenditure per individual. Expenditure is discounted at 2010 prices. *Source:* Our elaboration on balance sheet data of Italian local governments for the period 2000–2015 provided by the Ministry of Interior. The shapemap of the 2016 administrative borders is provided by the Italian Institute for Statistics [Color figure can beviewed at wileyonlinelibrary.com]