Shake me the money!*

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Abstract

We estimate the effect of local government expenditures on local economic activity. Following the 2009 L'Aquila earthquake, disaster relief grants from the Italian central government caused a large and unanticipated expansion in municipal government expenditures. Using a threshold in grant allocation to municipalities as an instrument, we find economic activity contracted similarly between municipalities that received grants and those that did not. The "disaster relief multiplier" is about zero and statistically below one. We provide evidence that suggests organized crime decreased the efficacy of grants. Our results contribute to the debate on the effects of COVID-19 recovery spending.

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1. Introduction

The question of the effectiveness of fiscal policy has been an important driver of policy and academic debates. Typically this efficacy is summarized by a numeric fiscal multiplier: the ratio of a change in output to the government expenditures that caused that output. Although papers have estimated the multiplier using different identification strategies, the literature is far from reaching a consensus. While many early contributions focused on measuring aggregate effects in a time-series context, recent papers have shifted their attention to the local dimension [25]. This shift is motivated both by specific policy questions—such as countering area-specific recessionary shocks—and by the opportunity to address identification issues [26, 1, 30]. For example, fiscal policy responds to economic conditions that also affect variables of interest, such as output and employment [14, 81]. Moreover, fiscal spending and transfers may coincide with other changes in monetary policy or taxation, making it difficult to disentangle effects of specific policies [64, 25]. Cross-sectional approaches that exploit plausibly exogenous variation in local fiscal stimuli allow researchers to better control for these concerns.

This paper contributes to the literature on the effects of local fiscal policy, in particular expanding on work by Yang, Fidrmuc, and Ghosh [95, 96]. We rely on a unique natural experiment resulting from characteristics of the institutional allocation of public grants from the Italian central government to local municipalities damaged by the 2009 L'Aquila earthquake in the Italian region of Abruzzo. Specifically, following the earthquake, specialists from the Civil Protection Department (CPD) and the National Institute of Geophysics and Volcanology (INGV) visited the epicentral area to survey the affected buildings.[1] In addition to assessing damages to specific buildings, each municipality was assigned a rank

[1]The CPD is a structure of the Prime Minister's Office that coordinates and directs the national service of civil protection. When a national emergency is declared, it coordinates the relief for the entire national territory. It coordinates activities in response to natural disasters, catastrophes, or other events that, due to their intensity and extent, must be tackled using special means and powers. In this case, the council of ministers declares a "state of emergency" by issuing a law by decree and identifies actions to be undertaken to manage the event.

based on the Mercalli scale, which classifies the destructive effects of an earthquake on a scale of twelve, ranging from "instrumental" (I) to "catastrophic" (XII).[2] After the damages were assessed and ranks were assigned, the central government enacted a law that provided disaster relief grants for rebuilding to municipalities with Mercalli ranks at or above VI. Municipalities below VI were not given grants. Unlike damages, which declined gradually from the epicenter, the law created a sharp threshold in grant eligibility that we use to identify the effect of grants on local economic activity. Furthermore, the specialists from the CPD and the INGV were unaware of the threshold for grant eligibility when assessing municipal damages, so the specialists could not manipulate which municipalities were eligible for grants.

Using data for 305 municipalities in the Abruzzo region from 2002 to 2011, our econometric approach relies on an instrumental variables (IV) strategy that uses a municipality's Mercalli rank with respect to the eligibility threshold as an instrument for grants. Conditional on assessed damages and distance to the epicenter, we argue that "treatment" municipalities above the threshold were exogenously given grants, whereas "control" municipalities below the threshold were not. Therefore, conditional on local damages, a municipality's position above or below the threshold only affected local economic activity because of grants.

Using our preferred measure of municipal output—declared personal income for tax purposes—we estimate that these disaster relief grants did not increase output within the first couple of years after the earthquake. Our IV estimates of the "disaster relief multiplier" remain close to zero in all specifications and are statistically well below one on impact through two years after the earthquake. Reinforcing our inference that there was a lack of an effect of grants on output, when we use our IV model to estimate the effect of grants on other measures of municipal economic activity that do not depend on municipal tax collec-

[2]Contrary to the well-known Richter scale, which quantifies the moment magnitude (energy) of an earthquake, the Mercalli scale classifies the destructive effects of an earthquake. While every quake has only one magnitude recorded at the epicenter, the destructive effects (and therefore the Mercalli ranks) vary across geographic areas according to a large set of factors including the distance from the epicenter or the pre-earthquake vulnerability of buildings.

tion and are not affected by potential tax evasion caused by the earthquake—value added in the construction sector, population, and night lights visible from space measured using high-resolution satellite data—we still do not find that grants affected any of these measures.

We check to see whether general equilibrium forces confound our cross-sectional estimates. For example, trade and labor flows between municipalities that received grants and those that did not may have resulted in import leakage or otherwise cause the observed differences in economic activity to reflect these forces in addition to grants [10, 52, 28, 45]. To address this concern, we employ a donut regression [9] approach excluding geographically bordering treatment and control municipalities that possibly have tighter economic linkages. In these donut results and other robustness checks, we consistently find a disaster relief multiplier very similar to our full sample of municipalities of close to zero and statistically well below one.

One critique of any policy evaluation is whether expectations of future policies play a role in a researcher's estimated effects. In the context of multipliers following a fiscal expansion, expectations of future government stimuli may lead an estimated multiplier to reflect a combination of the economic effects of the realized government expenditures plus these expectations, which would bias up estimates of the on-impact multiplier.[3] In our context, anticipation of additional disaster relief grants beyond those that were authorized is unlikely to explain our finding of a zero multiplier, as potential bias would lead us to overstate the multiplier. We do not find an effect of grants in any year on impact through two years after the earthquake, so intertemporal shifting, at least during our sample period, cannot explain our findings. Because we consistently find no effect of grants on any measure of local economic activity and anticipation effects are unlikely to be a factor in our inference, we conclude that these grants did not act as a public insurance program that would soften the output loss from the earthquake.[4]

[3] An entire strand of the literature uses variation in fiscal policy from military buildups to control for expectations of future fiscal policy [11, 81].

[4] Although Italy is one of the most seismic countries in the world, households and firms cannot insure

Our estimate that the grants did not affect economic activity is at the bottom of the literature's range of cross-sectional fiscal multiplier estimates [80, 25]. We, therefore, investigate two possibilities as to why these disaster relief grants did not stimulate economic activity.

One potential story is that the rebuilding supposedly financed by the disaster relief grants would still have occurred even in the absence of Italian central government financing. If this story were the case, then we might observe an increase in (re)construction spending after the earthquake throughout Abruzzo, regardless of whether municipalities received a disaster relief grant, with construction possibly financed by private sources, non-government entities, or self-financed by municipal governments. That said, we do not find an increase in construction spending for Abruzzo's municipalities after the earthquake, regardless of disaster relief grant receipt, relative to municipalities not damaged by the earthquake in regions near Abruzzo. Therefore, we think that this story is inaccurate.

A second potential story for why grants did not improve economic activity is that structural characteristics of municipalities, such as poor governance or meddling by organized crime, eliminated the stimulative effect of grants. We use narrative evidence, which includes documentation on arrests of politicians and local grant administrators, and other investigative reports to provide support for this story.

Our setting provides estimates of the efficacy of fiscal spending after a natural disaster. As an earthquake of the magnitude of the L'Aquila earthquake and the buildings that were damaged or destroyed were obviously unanticipated and disaster relief grants were distributed within a month of the earthquake, rebuilding projects supposedly financed by the grants were focused on restoration and were not pre-planned "shovel ready" projects to expand pre-earthquake infrastructure, so our estimated zero multiplier can be interpreted in that context. As certain natural disasters—such as droughts, floods, or the storm surges from hurricanes and cyclones—become either more destructive or occur more frequently be-

against seismic risks because no there is no private insurance market.

cause of climate change [93, 58], sound estimates of the effects (or lack thereof) of disaster relief spending will also become more important. Our results suggest that simply throwing money at rebuilding infrastructure after a natural disaster may be ineffective on its own. Likely other safeguards must complement the fiscal spending to ensure aid is well spent.

Our analysis more broadly expands the literature's understanding of the effects of fiscal policy by offering a complementary perspective from Italy. While our paper is closely related to the cross-sectional multipliers literature using sub-national data, most of these papers look at the United States [42, 87, 59, 88, 64, 92], such as those that look at the American Recovery and Reinvestment Act [26, 60, 25]. In Italy, corruption and criminal institutions may be stronger influences over economic outcomes than in the United States [16, 76, 1, 8].

Our results and setting—no effect of government spending following a disaster—also have broad applicability to the current debate on the potential effects of another set of disaster relief programs: COVID-19-induced fiscal expansions. For example, in the second half of 2020, the European Commission was authorized to raise 750 billion euros from capital markets on behalf of the European Union (EU), or almost 5% of euro-area gross domestic product (GDP), to finance a coordinated fiscal expansion across the EU. In five years, Italy will receive up to 209 billion euros, amounting to about 13.5% of its 2021 GDP, becoming the largest beneficiary member state (in euros). According to the Italian government's official estimates [54], these funds might increase GDP growth by an average of 0.6 p.p. per year from 2021 to 2026. That said, this growth estimate assumes that public investment will be implemented efficiently.

Is this growth estimate too optimistic? Possibly so. Likely the Italian government will need other guardrails and sufficient oversight–better than those in place for overseeing the L'Aquila disaster relief grants–to ensure that future spending will cause economic growth.

2. The 2009 L'Aquila Earthquake and the Disaster Relief Grants

At 3:32 am local time on April 6^{th}, 2009, a 6.3 magnitude earthquake shook the southern part of Italy. The epicenter was 10.15 kilometers east of L'Aquila, the capital city of the

Abruzzo region (Italy is divided into regions composed of provinces, and provinces contain municipalities. See figure 1).[5] Over 300 people were killed and more than 1,500 were injured. Following the declaration of a state of emergency by the Council of Ministers, a team of specialists from the CPD and the INGV visited the epicentral area to assess the severity and extent of damages. The assessment lasted ten days and on April 16^{th} the list of affected municipalities and the estimates of damages were made publicly available and sent to the central government.

During their mission, the specialists had two separate tasks. First, they visited each building, assessed damages (or suspected damages), and assigned damage levels to each building following the AeDES international classification system. This system categorizes civil structures after a seismic event into six levels ranging from "A" ("usable building") to "F" ("unusable building and severe external risks").[6]

For the second task, the specialists assigned a rank from the Mercalli scale to the municipalities in the epicentral area according to the severity of the damages. The Mercalli scale quantifies the effects of an earthquake on the Earth's surface as well as on humans, objects of nature, and buildings into twelve ranks ranging from I ("instrumental") to XII ("catastrophic"). Classifications between ranks are also allowed (e.g., VI-VII is between VI and VII). Appendix B reports the definitions of the Mercalli ranks, while figure 2 plots a map of the Abruzzo region that highlights each municipality in Abruzzo according to its Mercalli rank. Because of the extent and severity of the damages in the epicentral area,

[5] Abruzzo is a southern region of Italy composed of 4 provinces (L'Aquila, Chieti, Teramo, and Pescara) that contain 305 municipalities (comuni) for a total 1.3 million inhabitants. The time and coordinates of the earthquake are from the INGV [67]. We create our maps using spmap, which is created by Pisati [77, 78]; shapefiles from GADM [43]; and supporting code from Picard [73, 74], Picard and Stepner [75].

[6] The six levels are defined as follows. A: "usable building"; B: "usable building after short-term measures"; C: "partially unusable building"; D: "temporarily unusable building"; E: "unusable building"; F: "unusable building and severe external risks". For details see Baggio, Bernardini, Colozza, Corazza, Della Bella, Di Pasquale, Dolce, Goretti, Martinelli, Orsini, Papa, and Zuccaro [7]. Out of 75,424 buildings visited by the CPD and INGV, specialists assigned 55.2 percent to level "A", 16.5 percent to "B", 3.4 percent to "C", 1.9 percent to "D", 20.4 percent to "E", and the remaining 2.6 percent to "F" with no significant differences across types of buildings. Table A.6 in Appendix A shows the distribution of damages across different types of buildings.

the specialists did not distinguish between Mercalli ranks below V and assigned a 0 instead, although AeDES levels were still assigned to buildings in these municipalities.[7]

Twelve days after the completed damage assessments the central government was shaken into action and enacted a law by decree ("Decreto Legge 28 Aprile 2009, n.39") establishing a qualifying Mercalli threshold to receive disaster relief grants for rebuilding.[8] The threshold for grants, which was unknown to the CPD and INGV specialists when they assigned Mercalli ranks, was fixed at VI, which is the lowest rank associated with structural damages to civil structures. The only municipalities that qualified for disaster relief grants were those with a Mercalli rank equal to or above VI.[9] The L'Aquila grants allocation rule was also unique because it was not followed when distributing disaster relief after strong earthquakes in other parts of Italy, so specialists were unlikely to correctly guess the L'Aquila allocation rule. Figure 3 plots average per-taxpayer grants by Mercalli rank.[10] Out of 305 municipalities in Abruzzo, specialists ranked 248 at V-VI or below and 57 at VI or above. Therefore, 57 municipalities qualified for disaster relief grants while the other 248 did not.

While there are always some non-disaster municipal grants, "Decreto Legge 28 Aprile 2009, n.39" caused a large increase in grants only for qualified municipalities. Grants, on average, increased from 2,020 real euro per-taxpayer in 2008 (non-disaster) to 10,677 in 2009 (disaster plus non-disaster), considering both the current and capital components of grants.[11] Non-qualified municipalities, which continued to have only non-disaster grants, experienced

[7]Most of the time the CPD and INGV specialists ranked municipalities between ranks when the damages did not fully match the description of one the ranks for the L'Aquila earthquake. Table A.7 in Appendix A shows the 2009 distribution of Mercalli ranks across the provinces of Abruzzo.

[8]For completeness, we report the original text (in Italian) from the law by decree ("Decreto Legge 28 Aprile 2009, n.39"): "I predetti provvedimenti hanno effetto esclusivamente nei confronti dei comuni interessati dagli eventi sismici che hanno colpito la regione Abruzzo a partire dal 6 aprile 2009 che, sulla base dei dati risultanti dai rilievi macrosismici effettuati dal Dipartimento della protezione civile, hanno risentito un'intensità MSC uguale o superiore al sesto grado".

[9]Mercalli ranks of "V-VI" and below are associated with more minor damage including cracked windows and doorframes, and broken toilet fixtures, walls or ceilings, but without apparent damage to the underlying structure of the building. See Appendix B for additional detail.

[10]All values in per-taxpayer terms use the number of personal income taxpayers.

[11]We deflate all monetary values using the regional consumer price index from the Italian National Institute of Statistics (ISTAT) [53] with 2010 as the base year.

almost no change in grants (on average, from 1,246 in 2008 to 1,396 in 2009).

Given the high marginal utility of government spending in the aftermath of the earthquake, the increase in grants for qualified municipalities caused an almost euro-for-euro increase in their average municipal government spending, whereas spending by non-qualified municipal governments changed little.[12]

3. Data and Pre-treatment Trends

Our data set is an annual balanced panel of 305 municipalities in Abruzzo over 2002 - 2011.[13]

The municipal budget accounts ("certificati consuntivi") released by the Italian Ministry of Interior [33] provide data on municipal government grants, spending, and revenues recorded on an accrual basis. We define grants as the sum of current and capital appropriations from the central government to municipalities. We deflate monetary variables using the regional consumer price index from the Italian National Institute of Statistics (ISTAT) [53], with 2010 as the base year.

We aim to estimate the short-run effects of disaster relief grants on municipal economic activity following the 2009 L'Aquila earthquake. For our main measure of municipal economic activity, we use data on declared personal income per-taxpayer from the Italian Ministry of Economy and Finance [36].[14] Taxable income provides an accurate measure of local economic activity under the assumption that tax evasion does not vary systematically with

[12]Municipalities had to use disaster relief grants on costs associated with the L'Aquila earthquake. Some funds were designated for construction, but otherwise municipalities had broad latitude to spend disaster relief grants as they saw fit.

[13]Our choice eliminates 14 municipalities ranked at Mercalli V or V-VI in the neighboring region of Lazio. The earthquake did not generate Mercalli ranks higher than V-VI outside Abruzzo, so only municipalities in Abruzzo qualified for disaster relief grants. For these reasons, we prefer to restrict our attention to Abruzzo. The excluded Lazio municipalities are: Accumoli, Amatrice, Antrodoco, Borbona, Borgo Velino, Borgorose, Castel Sant'Angelo, Cittaducale, Cittareale, Fiamignano, Micigliano, Pescoracchiano, Petrella Salto, and Posta, all located in the province of Rieti.

[14]Our analysis uses the declared personal income per-taxpayer to control for the drop in the number of taxpayers due to the deferral of all tax obligations related to the 2008 financial year (the year before the earthquake). The deferral was granted to residents in the municipalities of L'Aquila province (independent of Mercalli rank). For municipalities below Mercalli VI, the deferral was up to November 30^{th}, 2009. For municipalities equal to or above Mercalli VI, the deferral was longer, up to December 20^{th}, 2010 [41].

Mercalli rank. To the best of our knowledge, these data are the best available measure of municipal-level economic activity in Italy.

All earthquakes-related geophysical data, including Mercalli ranks, come from the INGV ("2011 Italian Macroseismic Database ($DBMI11$)") [66].[15]

Fundamentally, our study compares the local economic activity of qualified "treatment" municipalities ranked at or above the Mercalli VI threshold, which received disaster relief grants, to the activity of the non-qualified "control" municipalities below the threshold. A concern with our approach may be that municipalities at or above the Mercalli VI threshold had different trends in grants or income before the L'Aquila earthquake than those below the threshold. In such a case, our approach could incorrectly attribute the differences in income between treatment and control municipalities after the earthquake to grants, whereas we would actually just be picking up differences in pre-existing trends.

To investigate this concern, we begin by comparing the unconditional trends of grants and income of the treatment and control municipalities.

Figure 4 shows the event study for grants, plotting the annual difference in mean real per-taxpayer grants between treatment and control municipalities, with the difference in the year before the L'Aquila earthquake set at zero. The figure shows that, before the L'Aquila earthquake, treatment and control municipalities exhibited parallel trends in grants. The difference in mean grants before the earthquake is never statistically different from zero. That said, there is a huge increase in treatment municipality grants starting in the year of the earthquake, which supports our use of "Decreto Legge 28 Aprile 2009, n.39" as a relevant source of variation in municipal grants.

Figure 5 shows the analogous event study for personal income. Similar to grants, the mean incomes for treatment and control municipalities had parallel trends before the earth-

[15] The INGV records Mercalli ranks for other earthquakes besides the 2009 L'Aquila earthquake, but the only major earthquake (and the only earthquake to cause disaster relief grants) in our considered period is the 2009 L'Aquila earthquake. Table A.8 in Appendix A reports the distribution of Mercalli ranks by year for all INGV recorded events, which shows that the 2009 L'Aquila earthquake was the only earthquake to cause a Mercalli rank of VI or higher.

quake, as the difference is never statistically different from zero. Taken together, the parallel trends in figures 4 and 5 mitigate concerns over pre-existing differences in the types of municipalities that received grants versus those that did not.

Figure 5 also shows our first estimates of the causal effect of grants on income. Although "Decreto Legge 28 Aprile 2009, n.39" caused a huge increase in grants in 2009 and thereafter, there is no discernible increase in income over the same period. For reference, the average difference in grants between treatment and control municipalities in 2009 (i.e., the size of our treatment in 2009) is shown by the horizontal red dashed line in figure 5.

Although our event studies show no increase in income as a result of receiving disaster relief grants, the event studies show unconditional differences in mean estimates. It is possible that other observable factors–in particular the negative supply shock due to damages–when appropriately conditioned for would allow us to find an effect of grants on income. To allow for other observable factors, we turn to instrumental variables (IV) estimation.

4. Instrumental Variables (IV) Model

For each municipality i, let $y_{i,t}$ denote real per-taxpayer personal income in year t. Let $g_{i,t}$ denote the real per-taxpayer value of grants. Following the recent literature [11, 1], we estimate a "disaster relief multiplier", β, that relates $y_{i,t}$ to $g_{i,t}$.

Our baseline empirical strategy is based on a linear fixed-effect panel data model:

$$y_{i,t} = \alpha_i + \lambda_t + \beta g_{i,t} + \gamma' E_{i,t} + \eta_{i,t}, \tag{1}$$

where $E_{i,t}$ is a set of variables capturing the negative supply shock generated by the earthquake in 2009, such that γ' provides a measure of the direct negative effect of the earthquake on income, and $\eta_{i,t}$ is a disturbance term. The municipality (α_i) and time (λ_t) fixed effects capture the effects of unobserved time-invariant municipal heterogeneity and aggregate shocks that affected all municipalities in Abruzzo, such that β only captures the same-year effect of grants net of these shocks.

Ordinary least squares (OLS) estimates of equation (1) could create identification issues. Estimates of the multiplier, β, could be biased because grants are endogenous to local business cycles and needs. Even in our context, simply controlling for the supply shock with $E_{i,t}$ may not fully resolve these issues, as the correlation between grants and the supply shock would make it difficult to disentangle the effects of grants from the direct effects of the earthquake.

The eligibility threshold for disaster relief grants is how we overcome identification issues. We use a dummy for qualified municipalities (those with a Mercalli rank at or above VI) as an instrument for $g_{i,t}$. Our just-identified first-stage IV regression, equation (2), is a difference-in-differences regression for grants:

$$g_{i,t} = \alpha_i + \lambda_t + \delta_1 MercalliThreshold_{i,t} + \delta_2' E_{i,t} + \xi_{i,t}, \tag{2}$$

where $MercalliThreshold_{i,t}$ is an indicator that takes a value of 1 for those municipalities ranked at or above Mercalli VI because of the L'Aquila earthquake starting in 2009.

The intuition for the IV estimator is straightforward: $MercalliThreshold_{i,t}$ isolates exogenous variation in grants around the eligibility threshold, purging the grants variable of variation that may be spuriously correlated with local economic activity.

The IV estimator identifies the causal effect of grants on output under two assumptions. First, the instrument must be a relevant predictor of the endogenous variable. We have seen already from figure 4 that qualified treatment municipality grants skyrocketed relative to non-qualified control municipality grants in 2009. Furthermore, as we will show in our results, $MercalliThreshold_{i,t}$ in equation (2) predicts grants with reasonable first-stage F-statistics for identification.

The second identification assumption for the IV estimator is the exclusion restriction that our instrument, $MercalliThreshold_{i,t}$, is uncorrelated with the error term $\eta_{i,t}$ in equation (1). This assumption means that the only reason municipalities above and below the Mercalli VI threshold differed in economic activity was due to grants.

While the exclusion restriction assumption for just-identified IV cannot be tested directly, our event studies, shown in figures 4 and 5, provide indirect evidence that this assumption is reasonable. Both grants and income had similar trends between treatment and control municipalities before the earthquake. Equation (2) is also just-identified, using one instrument for one endogenous regressor, and just-identified IV is median-unbiased. We also do ***not*** find that our instrument predicts grants or income before the earthquake.[16]

Even ruling out pre-existing differences in trends of grants or income, you may worry that treatment municipalities may have reacted differently than control municipalities to the earthquake itself, leading to differences in income between treated and control areas after the earthquake that are unrelated to the grant allocations. To address this concern, in all specifications we include a set of controls $E_{i,t}$ that capture the direct effect of the earthquake on local economic activity.

For part of $E_{i,t}$ we create a measure of damages to buildings by aggregating and summarizing building-level damages data from the CPD. Our summary index, $Damages_{i,t}$, is a weighted average of municipal AeDES levels assigned by CPD specialists:

$$Damages_{i,t} = \frac{\sum_{k=A}^{F} \omega_k \cdot Buildings_{k,i}}{TotalBuildings_i} * Post2008_t \tag{3}$$

where weights on building damage ratings are $\omega_A = 0$, $\omega_B = 0$, $\omega_C = 0.5$, $\omega_D = 0.5$, $\omega_E = 1$, $\omega_F = 1$; $Buildings_{k,i}$ is the number of buildings assessed at level k in municipality i due to the L'Aquila earthquake; $TotalBuildings_i$ is the total number of buildings in municipality i in 2009; and $Post2008_t$ is a dummy equal to 1 starting in 2009.[17] Data on 75,424 AeDES classified buildings and damages come from the CPD [27]. $Damages_{i,t}$ captures both the

[16]Specifically, we run cross-sectional IV models of grants and income, controlling for $E_{i,t}$, for the three years before the earthquake (2006-2008) on grants, instrumented with $MercalliThreshold_{i,t}$, for each year after the earthquake (2009-2011). For example, we regress 2006 grants on 2009 grants, instrumented with $MercalliThreshold_{i,t}$; regress 2006 grants on 2010 grants, instrumented with $MercalliThreshold_{i,t}$; and so forth. There are no instances where instrumented post-earthquake grants predict pre-earthquake grants or income.

[17]We estimate the total number of buildings using census data [53] assuming a constant growth rate in each municipality equal to the growth rate of the respective provinces.

severity (the AeDES damage levels) and the *extent* (the number of buildings categorized at or above AeDES level "C") of building damages. The advantage of using a summary index for building damages is that it reduces the need to estimate unnecessary parameters.

We also include the distance from the municipality to the epicenter for municipality-years starting in 2009, as well as its square, which serve as proxies for the direct effects of the earthquake that may not be reflected in our weighted index $Damages_{i,t}$.

5. Baseline IV Results

Table 1 reports the results of our baseline IV model (1).[18] The first column reports the OLS result of equation (1) while still controlling for the negative supply shock, $E_{i,t}$, along with time and municipality fixed effects. Results from OLS suggest that a real euro per-taxpayer increase in local government grants has almost no effect on local real per-taxpayer income. But, as we discussed earlier, OLS results might be biased, such as if grant allocations were to depend on municipal need or cyclical position.

Column 2 shows the first-stage IV regression (equation (2)). Consistent with the intuition captured by the event study in figure 4, the treatment indicator $MercalliThreshold_{i,t}$, which flags municipalities with 2009 Mercalli ranks at or above VI, positively and statistically significantly affects grants, providing evidence that grants increased sharply in treatment municipalities relative to control municipalities even when conditioning on fixed effects and $E_{i,t}$.[19]

The baseline second-stage IV result for the same-year response of local income to grants appears in column 3 of this table. The IV results confirm the event study of personal income from figure 5: despite conditioning on the negative supply shock $E_{i,t}$, conditioning on fixed effects, and isolating variation around the Mercalli VI threshold with $MercalliThreshold_{i,t}$, the IV model shows no significant effect of grants on same-year income.

[18] All models report standard errors clustered at the municipal level that are robust to serial correlation within municipalities and to heteroscedasticity across municipalities. Tables use Stata's esttab wrapper [55].

[19] We do not repeat the first-stage results in most of our alternate specifications, but we do continue to report the first-stage F-statistic on the excluded instrument for all specifications.

For a slight deviation from baseline, we also consider whether grants had a lagged effect on income in columns 4 and 5 of table 1. We replace the dependent variable with either income in the next year, $y_{i,t+1}$ (column 4), or income two years ahead, $y_{i,t+2}$ (column 5). We also do not find evidence of a lagged effect, which is supported by the event study in figure 5: income does not increase in the treatment group relative to the control group in any year after the earthquake.

Our estimated lack of an effect of grants on income is at the bottom of literature's range of cross-sectional fiscal multiplier estimates [80, 25]. Our estimates of the disaster relief multiplier are precise enough that we can easily reject multipliers of one on impact through two years after the earthquake, and anticipation effects cannot explain our findings.[20] Furthermore, even after scaling our estimated personal income multipliers to the municipal analog of gross domestic product, following Chodorow-Reich [25], we can easily reject multipliers of one.[21]

We now consider the possibility that our event study and IV estimates are spurious, such that the true effect was that grants stimulated income. That said, in the following investigations, much like in our event studies and baseline IV estimation, we find consistently small or no effects from grants.

6. Potential Identification Threats

In this section we explore four potential factors that could explain why our event studies and IV model, which both indicate no causal effect of grants on income, may spuriously do so: (1) the controls, (2) the income data, (3) the grants data, and (4) factor mobility or

[20] If anything, anticipation of future government expenditures would have increased income for treatment municipalities more on impact (in 2009) because of a pull forward of economic activity, which would bias up our estimates [81]. But from figure 5, income does not increase for the treatment group relative to the control group in ***any*** year after the earthquake, so intertemporal shifting cannot explain our results. Confirming the results of figure 5, we also estimated purely cross-sectional IV regressions of $y_{i,t}$, $y_{i,t+1}$, and $y_{i,t+2}$ on $g_{i,t}$ (instrumented with $MercalliThreshold_{i,t}$) and $E_{i,t}$ for each year starting in 2009. All of these IV regressions yielded a multiplier of zero.

[21] See Appendix C for details on the scaling.

import leakages. We present evidence that none of these four factors spuriously affect our results. Therefore, we assert that we have correctly identified that grants did not increase income.

6.1. Controls and Municipalities Near the Mercalli VI Threshold

It is possible that our baseline model, equation (1), lacks sufficient controls or that the controls that we do include for the negative supply shock from the earthquake, $E_{i,t}$, are misspecified. In either case, if variables in the disturbance term are correlated with grants, then the estimates of the disaster relief multiplier from our baseline model would be biased.[22]

We look at this possibility with five approaches. First, we augment our baseline IV model with a vector of other control variables, $X_{i,t}$:

$$y_{i,t} = \alpha_i + \lambda_t + \beta g_{i,t} + \gamma' E_{i,t} + \theta' X_{i,t} + \eta_{i,t}, \quad (4)$$

The introduction of $X_{i,t}$ changes our first-stage regression to:

$$g_{i,t} = \alpha_i + \lambda_t + \delta_1 MercalliThreshold_{i,t} + \delta_2' E_{i,t} + \phi' X_{i,t} + \xi_{i,t}, \quad (5)$$

In $X_{i,t}$ we include: casualties from the L'Aquila earthquake, population estimates, the fraction of children (14 and younger), and the elderly (65 and older).[23] Casualties and demographic characteristics attempt to capture how the earthquake may have interacted with the labor force and general civilian population in the area that may not be fully reflected in our baseline controls for the negative supply shock. Demographic variables are from ISTAT [53].

In our second approach, we saturate our negative supply shock vector, $E_{i,t}$, with the share of buildings classified by the CPD at each AeDES level interacted with $Post2008_t$ as well as the interaction of these classifications with our treatment variable. The motivation behind

[22] Because our model includes more than one regressor, the direction of potential bias is ambiguous.
[23] Population estimates are as of December 31^{st} of each year.

the change to individual AeDES levels is that it is possible $Damages_{i,t}$ is unnecessarily simplifying damages. The flexibility that comes with estimating more parameters might allow our IV model to more appropriately disentangle effects.

In our third and fourth approaches, we instead simplify $E_{i,t}$ to contain only $Damages_{i,t}$ or distance from the epicenter, which gives us more parsimonious representations of $E_{i,t}$, reducing the number of parameters we need to estimate.

In our final approach, we estimate our baseline model using only municipalities ranked from V to VI-VII, which are the ones nearest the threshold for disaster relief grants. In figure 2, these municipalities are in light red (VI and VI-VII) and dark blue (V and V-VI). Restricting the sample to these municipalities isolates the main source of variation in our instrument and ensures that the negative supply shock from the earthquake between the treatment and control municipalities is as similar as possible (though the cost for this approach is a smaller sample). Forcing the supply shock to be similar also mitigates potential non-linear effects of the shock on economic activity that our model may poorly fit. For example, if the supply shock to the hardest-hit treatment municipalities had an exponentially larger effect on economic activity relative to treatment municipalities right above the threshold, then our model may not account for this effect well. But restricting the sample to municipalities near the threshold removes this type of effect.

Table 2 shows the results of these approaches (more controls, AeDES levels, only damages in $E_{i,t}$, only distance in $E_{i,t}$, and municipalities near the Mercalli VI threshold). In all cases, the estimated effects of grants on income are not statistically different from zero and are well below one. The point estimates on grants in table 2 are also very similar to our baseline estimates, which gives us additional confidence that our baseline estimates are well-identified.

6.2. Personal Income Measurement Error or Tax Evasion

We now consider whether our main outcome measure of economic activity—declared personal income for tax purposes—is giving us correct inferences about the causal economic effect of grants. While we believe personal income is the best available measure of municipal economic activity in Italy as it uses administrative tax records, it is possible that measurement error of income, depending on the structure of the error and whether the error is a function of Mercalli rank, could either inflate or dampen our estimated effects. It is also possible that the Italian tax authority's data are tainted by tax evasion in some way that is correlated with Mercalli rank and disaster relief grants.

We take two approaches to address these concerns.

Our first approach to rule out the possibility that differential measurement error of income or tax evasion by treatment status drives our results is to ensure that our income data conform to Benford's Law [69, 12]. Loosely speaking, Benford's Law states that the first significant digits of certain naturally occurring processes, including most geometric processes, follow a logarithmic distribution.[24] The implication of Benford's Law is that, for these processes, smaller numbers (1, 2, 3) populate the distribution of first significant digits more frequently than larger numbers (7, 8, 9). The cross-sectional distribution of the first digits from the level of income should be described by Benford's Law, so forensic accountants have used deviations in this distribution from the one predicted by Benford's Law to detect tax evasion for at least the last twenty years, following the work of Nigrini [70]. That said, we find that our income data conform to Benford's Law and, most importantly, we do ***not*** find that this conformity depends on whether municipalities received disaster relief grants.[25] Therefore, Benford's Law shows no evidence that tax evasion depends on, or was caused by, a municipality receiving disaster relief grants.

Our second approach is to reestimate our baseline model using three alternative measures of Italian municipal economic activity for outcomes. These measures are all created by data

[24] For more details see Nye and Moul [71] or Michalski and Stoltz [62].

[25] Specifically, we test whether the first significant digits of the annual cross-sectional distributions of the level of real municipal income conform to Benford's Law using chi-squared tests. We run these annual tests for all municipalities and separately by treatment status. We are consistently unable to reject the null hypothesis that the income data conform to Benford's Law both before and after the L'Aquila earthquake. To address the concern of Nye and Moul [71] that mismeasured price indices may distort distributions of real variables away from what we should expect from Benford's Law, we also verify that our nominal income distributions conform to Benford's Law. We use code from Cox [31]. These tests support the results of Mir, Ausloos, and Cerqueti [63].

collection entities independent of the Italian Ministry of Finance.

Looking at other measures has two advantages in our context. First, it allows us to say something about the potential effects of disaster relief grants on other interesting municipal outcomes, as opposed to just their effects (or lack thereof) on income. Second, other measures of municipal economic activity that should, in theory, be correlated with income and have independent measurement errors—such as those created in a manner separate from Italian tax collection or the Italian tax authority—can provide a common signal that would improve estimates of the causal effect of grants on income [21, 65]. If we were to also estimate no effect of grants on these measures of economic activity, especially those that should not be affected by tax evasion driven by Mercalli rank, then it would make us more confident that our income estimates and associated inferences about municipal economic activity are correct.[26]

We use estimates of value added in the construction sector as a first alternative measure. These estimates are from surveys conducted by the private Italian banking association Osservatorio di Economia e Finanza [72]. Value-added data are attempting to quantify a similar economic concept as income data (value of goods and services). That said, the personal income data capture different portions of economic activity (income excluding firm profits) than these value-added data (construction spending). Furthermore, because Osservatorio di Economia e Finanza is independent from the Ministry of Finance, any measurement error in the Osservatorio di Economia e Finanza's data is not attributable to the agency-specific methods in which the Ministry of Finance creates its data and is also not attributable to potential tax evasion.

As a second alternative measure, we look at population estimates from ISTAT [53]. Presumably, damages from the earthquake could have caused people to relocate or prevented people from migrating to affected areas, and grants could have mitigated these effects.

[26] Validation of statistics using alternative, independently collected data is a practice used by national statistical agencies [13] and is also used to make inferences about latent variables [65, 24].

Finally, we supplement our alternative measures of local economic activity with high-resolution data on light density measured by satellites at night from the National Geophysical Data Center of the National Oceanic and Atmospheric Administration (part of the U.S. Department of Commerce) [68].[27] Night lights are positively correlated with types of human activity, such as greenhouse gas emissions and GDP [39, 38, 47]; are negatively affected by geophysical disasters [57]; and are not affected by potential tax evasion.[28]

Event study graphs for these alternative measures of economic activity (construction value added, population, and night lights visible from space) are in figures 6 - 8. The figures show parallel trends between treatment and control municipalities before the earthquake for all measures. The parallel trends before the earthquake across all measures further reinforces our view that the treatment and control municipalities are similar. Furthermore, after the earthquake, no statistically significant differences emerge for any measure.

The IV estimates for all measures are shown in table 3, which confirm that conditioning on the negative supply shock and fixed effects leaves us with the same inference as the event studies: grants did not affect economic activity.

6.3. Grants versus Spending

A potential difference between our estimates and some of those in the literature is that we have simply recovered the causal effect of municipal grants (appropriations) on local economic activity. Possible implementation lags between grants and spending could have implications on how we should interpret our results in a broader context [59, 92, 60].

That said, Abruzzo's municipalities spent grants from the central government quickly, and the earthquake did not change the rate of spending grants. Regressing year t*'s* real per-taxpayer municipal spending, $s_{i,t}$, which we take as current and capital obligations, on

[27] Appendix D provides a brief description of these data and more detail on how we use the lights. For additional detail on the lights data, see Elvidge, Baugh, Dietz, Bland, Sutton, and Kroehl [39]. These data are publicly available.

[28] Appendix A, figure A.11 reports the night lights density for 2007.

same-year grants and fixed effects separately for before and after the earthquake:

$$s_{i,t} \quad = \quad \alpha_i + \lambda_t + \theta g_{i,t} + \varepsilon_{i,t} \tag{6}$$

yields a pass through from grants to spending, θ, of about one-to-one both before and after the earthquake.[29]

The event study that compares spending between treatment and control municipalities, shown in figure 9, continues to show parallel trends in spending before the earthquake, followed by a massive increase in spending for treatment municipalities relative to control municipalities after the earthquake. Furthermore, the average increase in this spending, which was 7,400 euro per-taxpayer, was very close to the 7,300 euro per-taxpayer increase in average grants (see figure 4). While the demand for reconstruction increased dramatically in the wake of the earthquake, the fact that the pass through remained stable at about one-to-one and the fact that the average spending and grants event studies appear very similar to each other suggest that local governments deployed all grant funds quickly.

To instead recover the casual effect of spending, we reestimate our baseline IV table 1 specifications but use spending instead of grants. These models recover the causal effect of spending on economic activity under assumptions akin to the ones we made for grants.

Results from these models that use spending are shown in table 4. Not surprisingly, given the similarity of the grant and spending event studies and the one-to-one pass through from grants to spending, table 4 shows no effect of spending on income.[30]

6.4. Factor Mobility or Import Leakage (Stable Unit Treatment Value Assumption Violations)

There are a number of reasons why one euro of grants may lead to less than a one euro increase, or even no increase, in relative local incomes. You may be concerned that factor

[29] The pass through coefficient (standard error clustered at the municipal level) is 1.09 (0.10) pre-earthquake (2002-2008) and 0.99 (0.15) post-earthquake (2009-2011), which are not statistically different from one.

[30] It is also possible the grants data are mismeasured, but given that grants data are derived from administrative records, show a strong correlation with Mercalli rank, and that the spending data also indicate no effect of spending on income, we think mismeasurement in grants is unlikely to cause our results.

mobility or import leakage—both of which are more pronounced at local levels than they would be at a national level [25]—could potentially affect our estimated multiplier [10, 52]. For example, workers in control municipalities may work in neighboring treatment municipalities or benefit from increased demand after the earthquake for their goods and services from neighboring treatment municipalities. In either case, differences between treated and control localities may not reflect the true causal effect of the treatment because the treatment spills over across local borders. These cases would be examples of violations of what the treatment effects literature calls the Stable Unit Treatment Value Assumption (SUTVA) [84].

In order to address this concern and make our cross-sectional (small, open economy) multiplier estimates more aligned with a national (closed economy, without monetary response) multiplier discussed in much of the literature, we employ a donut regression approach,[31] estimating separate IV models that either (1) exclude all municipalities that border a municipality with the opposite treatment assignment, which form an estimation sample excluding the "donut hole", or (2) include only municipalities that border a municipality with the opposite treatment assignment (those that form the "donut hole"). Presumably factor mobility and import leakage are less likely between municipalities that are further apart geographically, so estimating our IV model excluding municipalities that border a municipality with the opposite treatment assignment would reduce the risk of a SUTVA violation. That said, these municipalities may be less similar. At the same time, including only municipalities that border a municipality with the opposite treatment assignment would increase the likelihood of a SUTVA violation but also make the treatment and control groups more similar. Particularly if we were to estimate a larger multiplier in the model that excludes all municipalities that border a municipality with the opposite treatment assignment relative to only including them, then that would suggest a SUTVA violation is the source (or at least a contributor to) our lack of estimated grant effects.

[31] We believe the term donut regression was first used by Barreca, Guldi, Lindo, and Waddell [9].

Results from the donut regressions in table 5 show that the estimated multiplier is remarkably similar and close to zero for both groups (columns 3 and 6). Though we cannot rule out spillovers to regions outside of Abruzzo, our donut regression results are inconsistent with the hypothesis that spillovers at municipal borders confound our local multiplier estimate.

7. Why Were Disaster Relief Grants Ineffective at Increasing Economic Activity?

So far we have shown that, in the few years after the L'Aquila earthquake, disaster relief grants were ineffective at increasing income and economic activity more broadly between qualified treatment and non-qualified control municipalities. Our estimates of the effect of grants on income are precise enough around zero that we can easily reject that a one-euro increase of grants caused a one-euro increase in income (i.e., reject a multiplier of one).

We now turn to some possibilities as to why the grants were ineffective. We provide some evidence that poor institutions or corruption reduced the efficacy of grants.

7.1. Reconstruction Regardless of Grants?

A possibility for why disaster relief grants did not improve the relative economic activity in the treatment municipalities is that rebuilding would have happened regardless of "Decreto Legge 28 Aprile 2009, n.39" and its grants, either because control municipalities self-financed rebuilding or other sources of non-public aid disproportionately financed rebuilding in control municipalities.

On municipal self-financing, we think this possibility is unlikely. Despite the huge increase in demand for reconstruction after the earthquake, control municipalities had little change in both grants and spending between 2008 and 2009, whereas treatment municipalities had large increases in both grants and spending.[32] There was also no means for the regional government

[32] Because Italian municipalities of at least 5,000 people were subject to the so-called "Domestic Stability Pact"—a stringent fiscal rule that capped municipal government stock and issuance of debt, budget balances, and expenditures net of disaster relief grants—municipalities of at least 5,000 people that did not qualify for

of Abruzzo or Abruzzo's provincial governments to increase spending for reconstruction.

Another potential scenario is the influx of non-public aid that flowed to Abruzzo after the earthquake to aid in rebuilding or otherwise mitigate the adverse humanitarian effects of the earthquake, which we are not able to capture as we only have data on public disaster relief grants, might have offset the relative effect of the public grants. If this non-public aid were disproportionately directed at non-qualified control municipalities (possibly to compensate for the lack of public financing), then we would estimate no effect of grants when construction could have increased in both qualified treatment municipalities due to the public grants and also increased in the non-qualified control municipalities due to the non-public aid.

To check whether non-public aid to control municipalities offsets our estimated effects and to give additional evidence that municipalities did not self-finance reconstruction, we turn back to our data on construction value added [72]. We compare the levels of construction within Abruzzo to construction in regions near Abruzzo, which were not damaged by the L'Aquila earthquake.[33] Abstracting from other regional shocks, if there were (re)construction due to non-public aid or self-financing, then we would expect an increase in construction within Abruzzo for both treatment and control municipalities, which were both damaged by the earthquake, yet no increase in construction outside of Abruzzo.

Figure 10 shows the results. The figure does not show a large increase in construction for Abruzzo's municipalities–regardless of disaster relief grant receipt–relative to municipalities not damaged by the earthquake in Abruzzo's neighboring regions. Restricting the municipalities in Abruzzo to Mercalli V to VI-VII, which were those nearest the grant threshold, yields a very similar picture. Obviously this comparison is somewhat tenuous as it assumes that the non-Abruzzo regions were not hit with some other shock after the L'Aquila earthquake

disaster relief grants were prohibited by law from borrowing extra funds or otherwise increasing spending [46, 17]. In practice, control municipalities below 5,000 people had similar expenditures after the earthquake to those control municipalities at or above 5,000, suggesting that non-legal constraints on borrowing or expenditures for disaster aid were binding.

[33] We have data for the regions of Basilicata, Campania, Molise, and Puglia, which are southeast of Abruzzo.

and that the non-Abruzzo regions are similar enough to Abruzzo to serve as a counterfactual.

That said, other evidence also suggests that control municipalities were not the targets of mass rebuilding financed by sources other than disaster relief grants. Indeed, not much rebuilding appears to have happened at all long after the earthquake. In October 2021 the municipality of Pratola Peligna, which was rated Mercalli V-VI and so did not receive disaster relief grants, announced a program to sell damaged houses for just one euro on the condition that the purchaser invest in rebuilding within three years [61].

All told, we take the lack of a jump in construction within Abruzzo after the earthquake, regardless of disaster relief grant receipt, as evidence that self or outside financing did not stimulate reconstruction.

7.2. Poor Institutions or Corruption?

Another possibility for why grants did not improve economic activity is that municipal governments were ill-equipped to use the disaster relief funds appropriately, possibly due to infiltration of the government or other shakedowns of public officials by criminal organizations. We do not have an econometric approach to answer this question, so instead we turn to the narrative record for evidence.[34]

Arrests in Abruzzo for money laundering two months before the earthquake [51] and another set of arrests for other alleged ties to the Mafia just three weeks before the earthquake [50] confirmed the presence and influence of organized crime in Abruzzo. Concern over organized crime assimilating municipal funds was apparent immediately after the earthquake. Caporale [23] noted that supposedly earthquake-proof buildings in the city of L'Aquila collapsed, leading to investigations and speculation that funds for construction before the earthquake were skimmed by organized crime and would continue to be after the earthquake. Others argued that the L'Aquila earthquake and subsequent aid that would flow to Abruzzo

[34] Previous research has found that criminal activity in Italy has adversely affected the supply of credit [16], has caused misallocations of business credits in the region of Sicily [8], and has depressed long-run output in the regions of Apulia and Basilicata [76].

would be a massive windfall for organized crime, increasing its presence in Abruzzo like flies drawn to sweet honey [86, 91].

Alarm about misuse of disaster relief aid in the weeks following the earthquake was such that, ten days after the earthquake (and twelve days before disaster relief grants were authorized by "Decreto Legge 28 Aprile 2009, n.39"), the attorney of L'Aquila assembled a special team of prosecutors to keep organized crime out of rebuilding efforts [90]. Italy's National Anti-mafia Prosecutor Pietro Grasso [18] and the head of Italy's lower house of parliament Gianfranco Fini [89] both made statements that said that organized crime was a factor that would need to be addressed during rebuilding, although their sentiments were brushed aside by then Prime Minister Silvio Berlusconi with his characteristic bravado. Berlusconi claimed everything would be rebuilt in a mere six months [49].

Sadly Berlusconi's rosy take on rebuilding is not supported by subsequent accounts on the ground (or this paper, for that matter). Investigative journalists and non-economist academics in the years after the earthquake have mostly focused on the city of L'Aquila, which did receive disaster relief grants. These accounts indicate a slow to non-existent pace of rebuilding, suggesting grants were not being spent effectively. Contreras, Blaschke, Kienberger, and Zeil [29], using fieldwork and images from Google Maps in 2010 and 2012, note that rebuilding was proceeding slowly in L'Aquila. Later investigative reporting by the Spanish public news corporation RTVE in 2010 [35], the British Broadcasting Corporation in 2013 [19], followed by CNN [85], the New York Times [79], and Reuters in 2016 [56] collectively point to a slow pace of rebuilding in L'Aquila. Later still, in September 2021—more than twelve years after the earthquake—Prime Minister Mario Draghi vowed to step up the effort to rebuild L'Aquila and other municipalities severely damaged by the 2009 L'Aquila earthquake by investing 1.78 billion euros of COVID-19 recovery funds. "It is necessary to accelerate the reconstruction due to the moral obligation we have with the citizens," Draghi said as he inaugurated the Park of Memory in L'Aquila [3].

Statements decrying the insufficient resources put into stopping organized crime from influencing rebuilding before it began [48] and subsequent law enforcement actions targeting misuse of disaster relief grants after they were allegedly used [2]–including the arrest of the Deputy Commissioner for Reconstruction, Luciano Marchetti, on suspicion of corruption, perjury, and issuing false invoices and the arrest of the Deputy Mayor of L'Aquila Roberto Riga on bribery charges [4, 20]–support the view that organized crime was profiting from and decreasing the economic effects of disaster relief grants. Furthermore, an independent investigation by the European Parliament [90] and subsequent independent investigations by journalists [20, 85, 79, 56] cite corruption as a factor in the inefficient use of disaster aid.

8. Conclusion

In this paper, we have contributed evidence on local fiscal multipliers. By relying on the L'Aquila earthquake, which was a large earthquake in the Italian region of Abruzzo, and a threshold in the formula for the associated public disaster relief grants as an instrumental variable, we found that these grants did not improve economic activity after the L'Aquila earthquake. Therefore, disaster relief grants did not provide public insurance against the earthquake's negative effects on local economic activity.

Our estimates of the disaster relief multiplier are consistently centered at zero and are precise enough that we can reject a multiplier of one. We provided evidence that organized crime or other structural characteristics of Abruzzo's municipal governments contributed to the lack of an effect of the grants. We also provided evidence against the hypothesis that rebuilding in Abruzzo proceeded regardless of grant receipt.

That said, the fact that disaster relief grants did not improve economic activity likely reflected a combination of factors in addition to (or interacting with) organized crime. Some possible other factors include that: disaster relief grants were mostly for rebuilding [22, 32, 15], the industrial concentration [37, 30, 6] or other institutional factors of Abruzzo or Italy [44, 42, 32, 34], slack [94, 5, 64, 82], or that the grants were setup quickly to specifically address the aftermath of a disaster. Nevertheless, it is likely that anti-corruption efforts are a necessary first step to ensure the efficacy of disaster relief or other public works programs. Indeed, a more recent Italian program that was also set up quickly to address a disaster—the COVID-19 vaccination drive—has also been hamstrung by organized crime [83].

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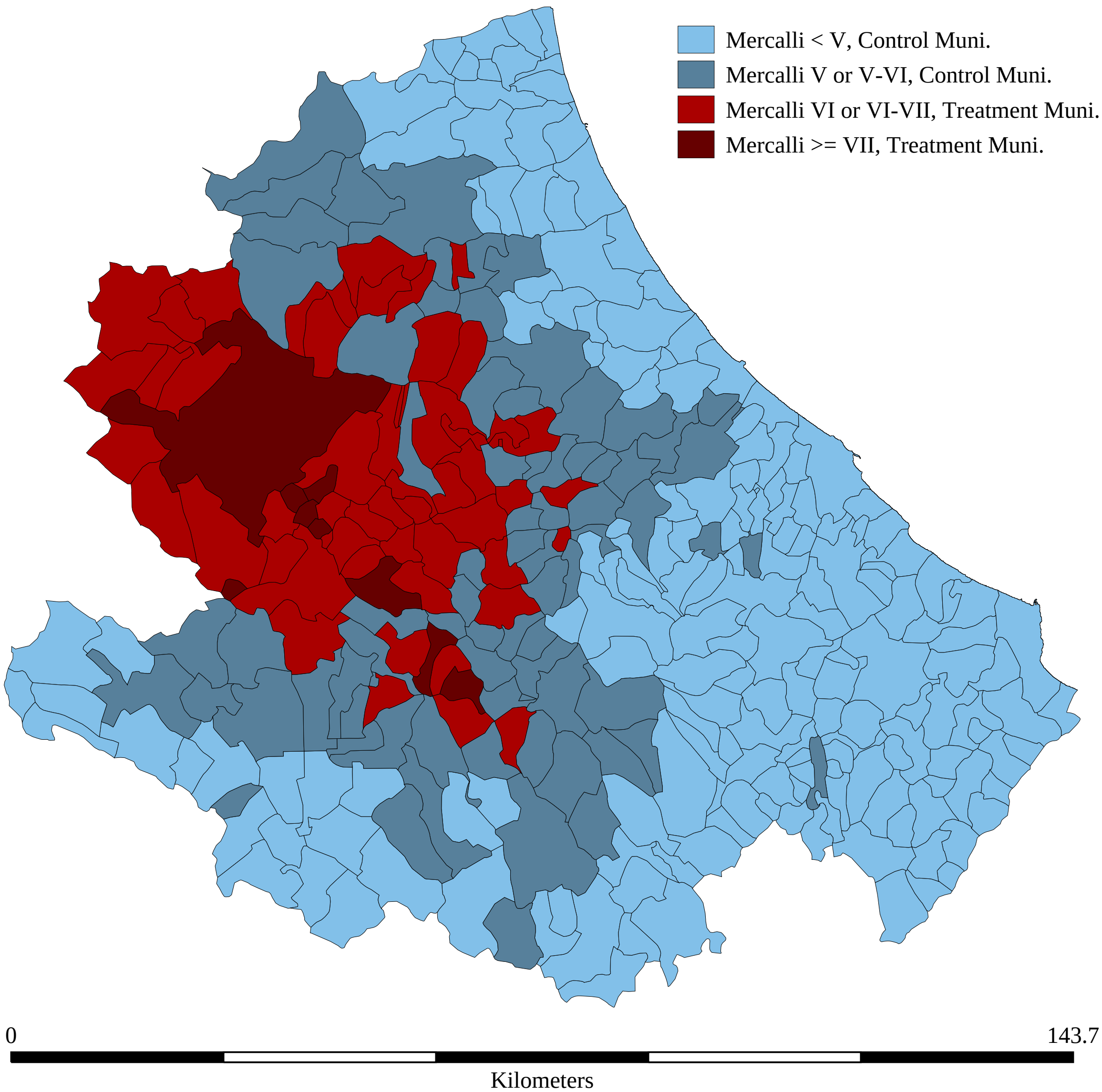
9. Figures

Figure 1: Map of Italian Regions

Description: Map of Italy's regions with Abruzzo in red. Web Mercator projection.

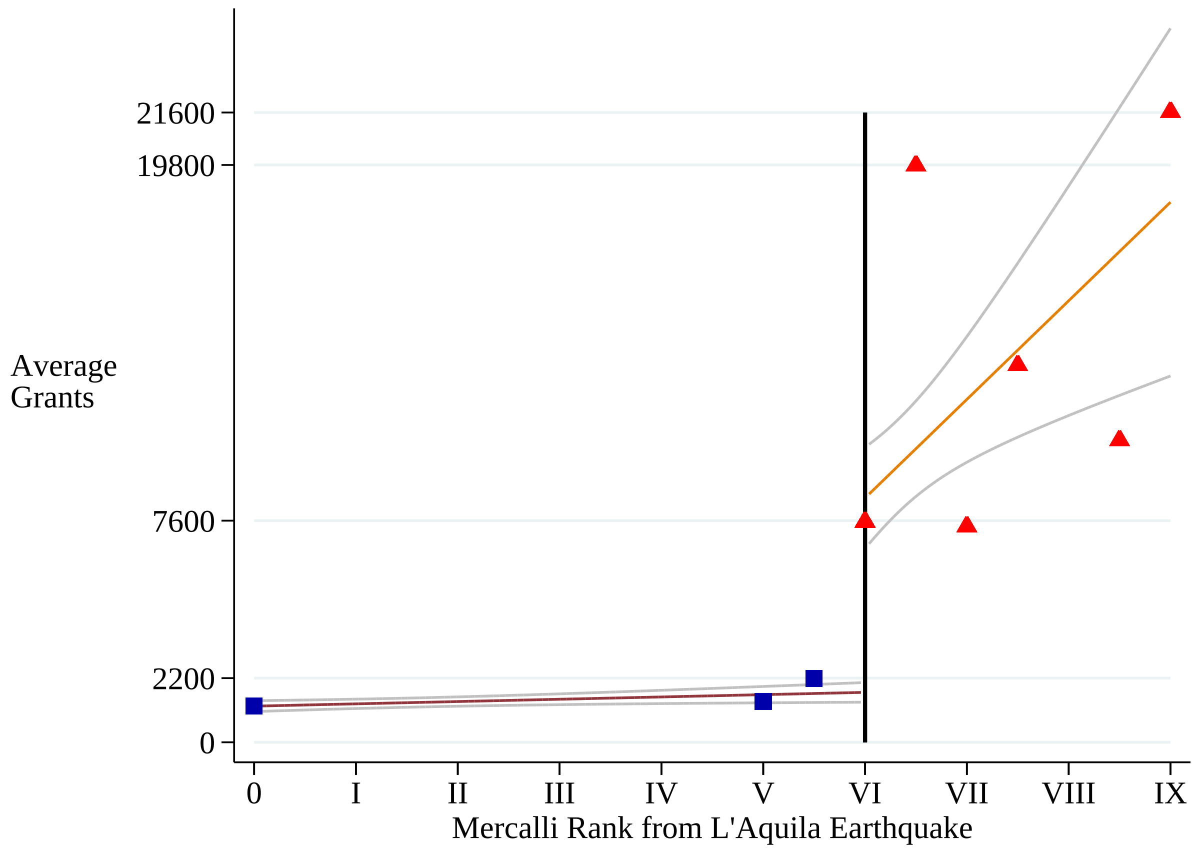
Figure 2: Map of the Abruzzo Region's Municipalities by Mercalli Rank



Description: Map of the Abruzzo region's municipalities. Web Mercator projection. Municipality colors correspond to Mercalli rank following the 2009 L'Aquila earthquake. Source: authors' calculations on INGV data [66].

Interpretation: The large dark red municipality in the northwest is L'Aquila, which was the epicenter of the earthquake. Our baseline sample compares red treatment municipalities to blue control municipalities. Our regressions that compare municipalities close to the Mercalli VI grants cutoff, shown in table 2, compare light red to dark blue municipalities.

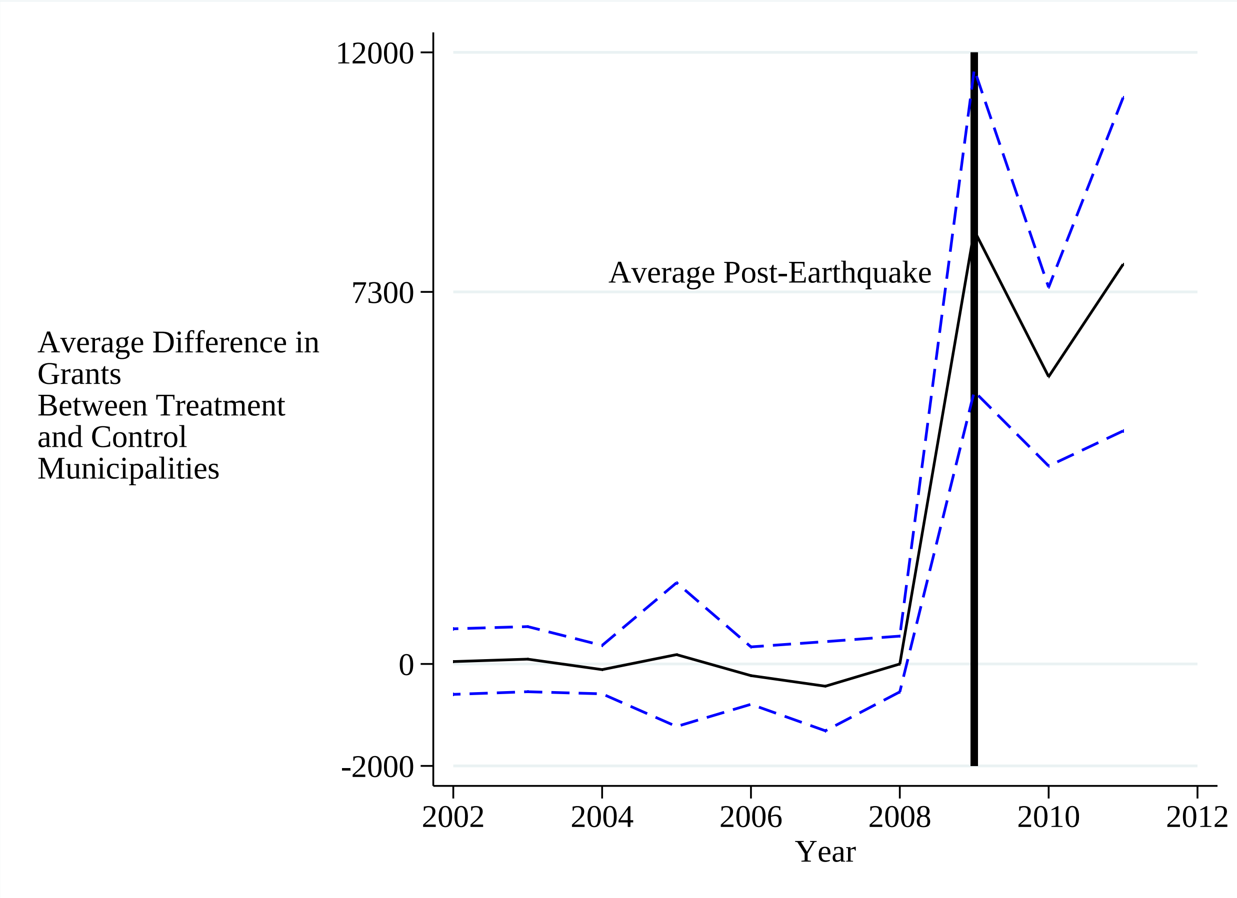
Figure 3: Discontinuity in Grants After the L'Aquila Earthquake Was Based on Mercalli Rank



Description: Figure plots total (disaster plus non-disaster) average annual grants, in 2010 real euro per-taxpayer, after the L'Aquila earthquake (2009-2011) by Mercalli rank. CPD and INGV specialists did not distinguish between Mercalli ranks below V and assigned a 0 instead. Municipalities that received disaster relief grants (Mercalli VI or higher) are shown by red triangles; municipalities that did not receive disaster relief grants, which had a Mercalli rank of below VI, are shown by blue squares. Linear regressions of grants on Mercalli rank with 95% confidence intervals are shown separately for municipalities above and below the Mercalli VI threshold. Source: authors' calculation based on data from the Italian Ministry of Interior [33] and INGV [66].

Interpretation: The L'Aquila earthquake and associated "Decreto Legge 28 Aprile 2009, n.39" had a discontinuous formula for receiving disaster relief grants, with the discontinuity at Mercalli VI. Municipalities at the Mercalli VI threshold had average annual grants (disaster plus non-disaster) of about 7,600 real euro per-taxpayer, whereas municipalities just below the threshold at Mercalli V-VI had average annual grants (non-disaster) of about 2,200 real euro per-taxpayer.

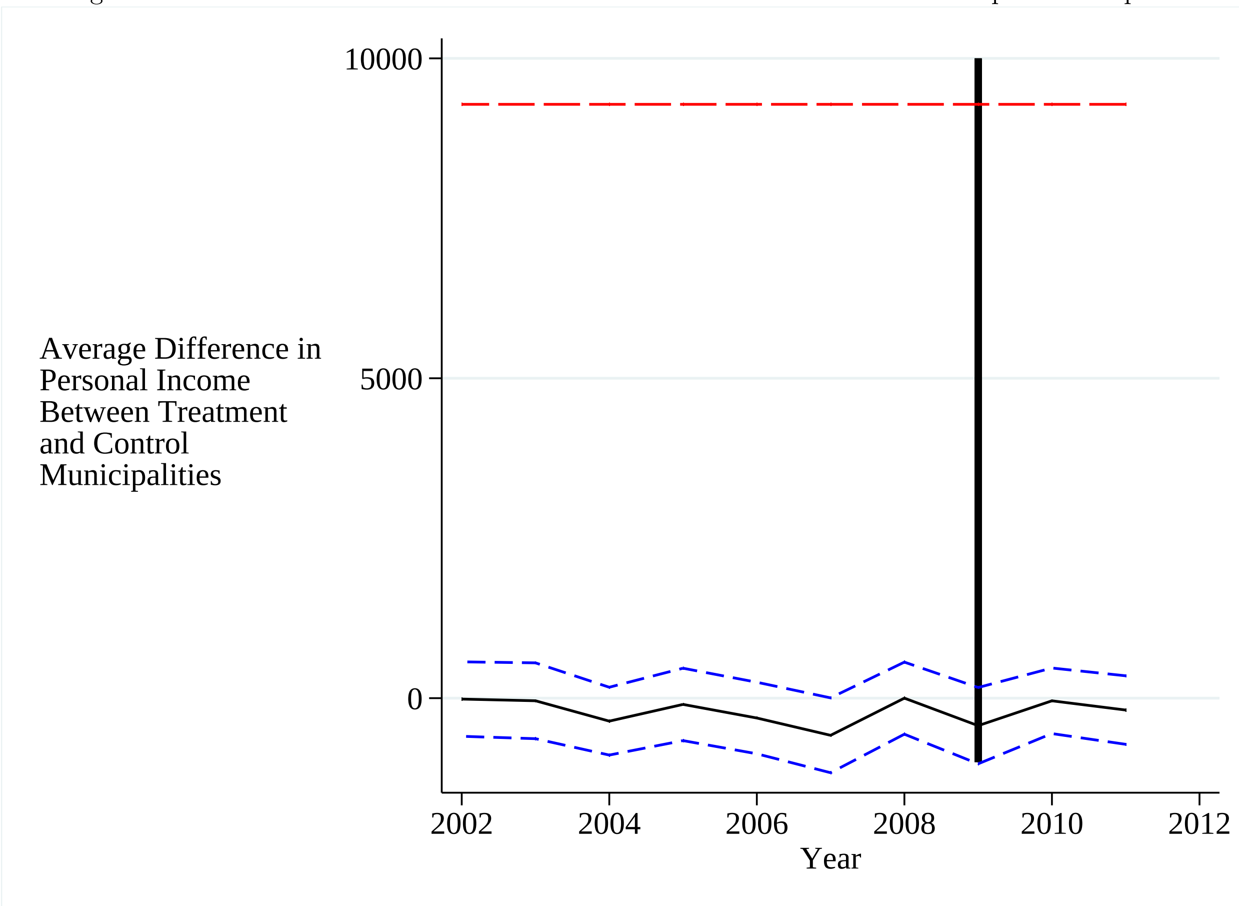
Figure 4: Treatment and Control Municipality Grant Trends Were Similar Before the 2009 L'Aquila Earthquake but Grants Increased for Treatment Municipalities After the Earthquake



Description: Figure plots the mean differences in municipal government grants, in real 2010 euro per-taxpayer, between the qualified treatment municipalities and the non-qualified control municipalities (black solid line) with 95% confidence intervals (blue short-dashed lines). The difference is centered at zero in 2008, the year before the earthquake. The black vertical line denotes the earthquake year. Source: authors' calculations and data from the Italian Ministry of Interior [33].

Interpretation: Before the 2009 L'Aquila earthquake, treatment and control municipalities had similar trends in grants. While there are always some non-disaster municipal grants, the L'Aquila earthquake and subsequent "Decreto Legge 28 Aprile 2009, n.39" caused a large increase in (disaster) grants for the treatment municipalities but not for control municipalities. On average, treatment municipality grants increased 7,300 euro per-taxpayer more than control municipalities after the L'Aquila earthquake (2009-2011).

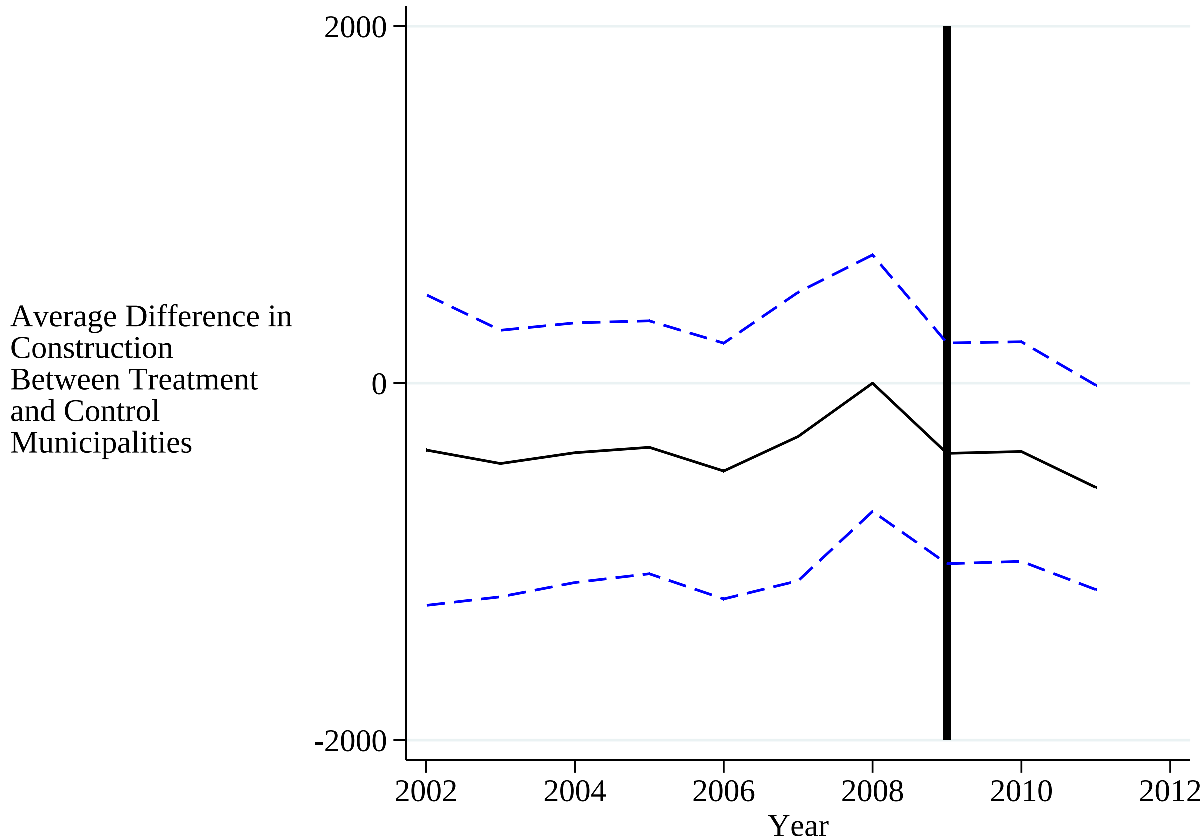
Figure 5: Personal Income Trends Were Similar Before and After the 2009 L'Aquila Earthquake



Description: Figure plots the mean differences in real 2010 euro per-taxpayer declared personal income between qualified treatment municipalities and non-qualified control municipalities (black solid line) with 95% confidence intervals (blue-short dashed lines). The difference is centered at zero in 2008, the year before the earthquake. The black vertical line denotes the earthquake year. The red horizontal long-dashed line denotes the average difference in real per-taxpayer grants between treatment and control municipalities in 2009. Source: authors' calculations and data from the Italian Ministry of Economy and Finance [36].

Interpretation: Before the 2009 L'Aquila earthquake, treatment and control municipalities had similar trends in average income. There was no increase in the income of treatment municipalities relative to control municipalities after 2009. Fluctuations in the difference in income between treatment and control municipalities after the earthquake are small and are much smaller than the average disaster relief grant, indicating that grants did not increase income.

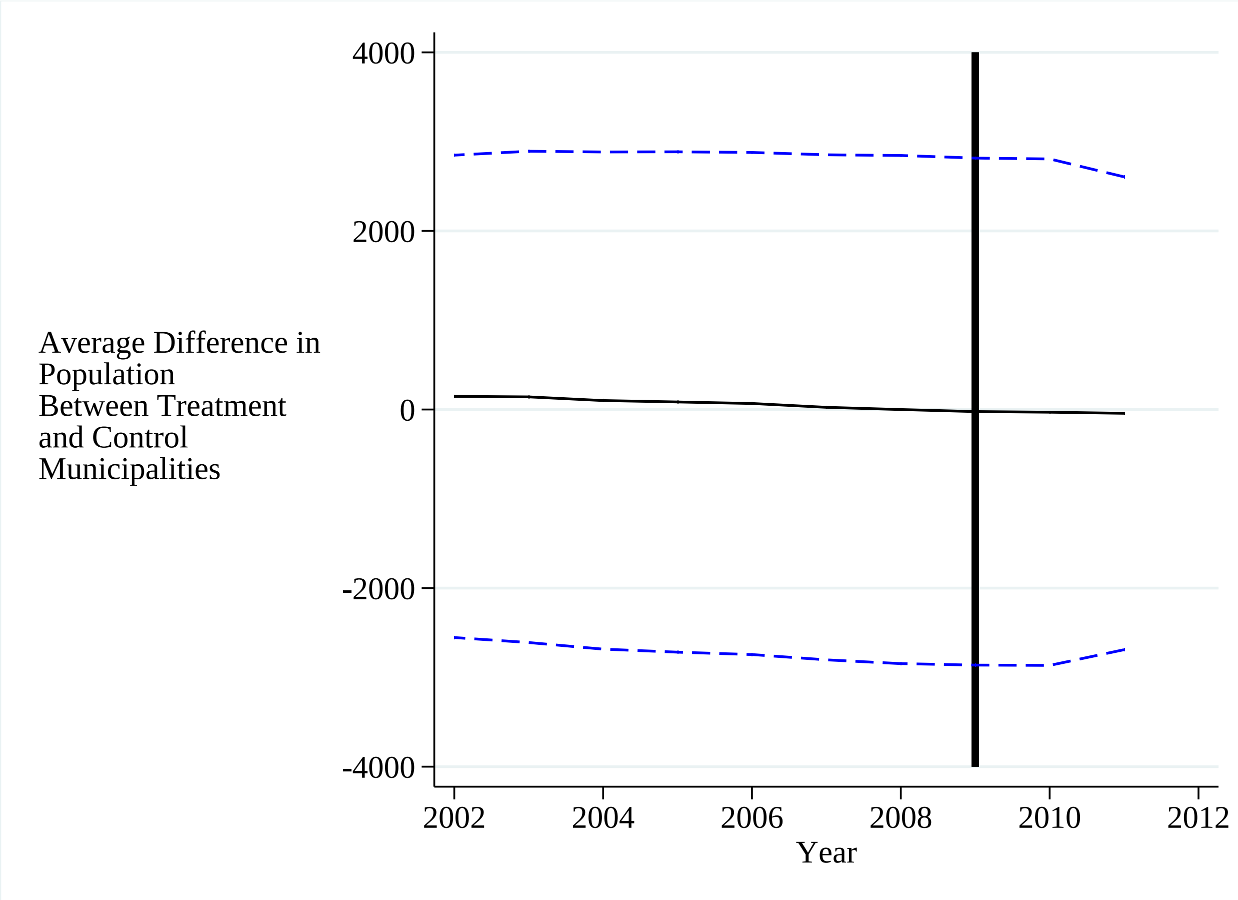
Figure 6: Municipal Construction Value Added Trends Were Parallel Before and After the 2009 L'Aquila Earthquake



Description: Figure plots the mean differences in real 2010 euro per-taxpayer construction value added between qualified treatment municipalities and non-qualified control municipalities (black solid line) with 95% confidence intervals (blue short-dashed lines). The difference is centered at zero in 2008, the year before the earthquake. The black vertical line denotes the earthquake year. Source: authors' calculations using data from Osservatorio di Economia e Finanza [72].

Interpretation: Before the 2009 L'Aquila earthquake, treatment and control municipalities had similar trends in construction value added. There is no increase in the construction spending of treatment municipalities relative to control municipalities after 2009, indicating that grants did not affect construction spending.

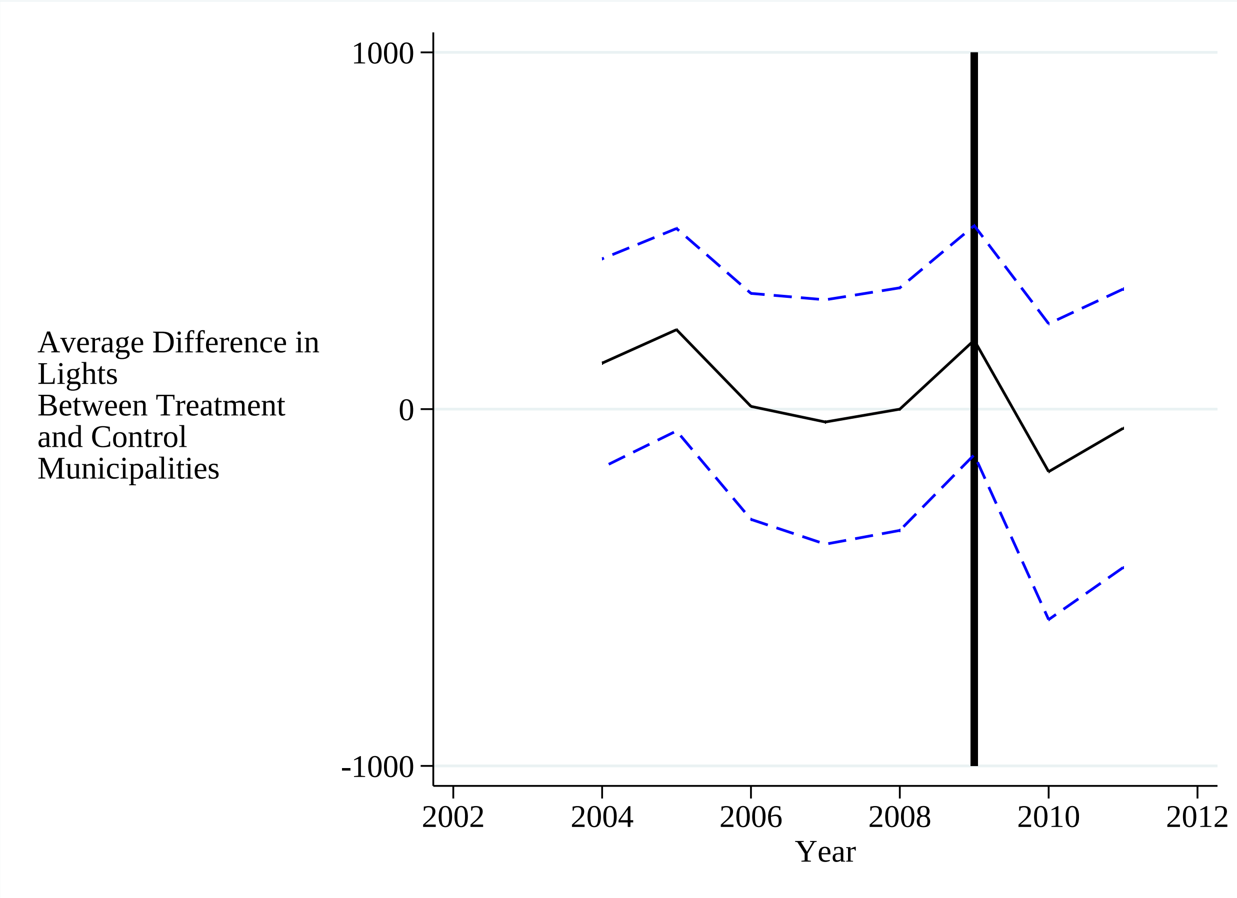
Figure 7: Population Trends Were Parallel Before and After the 2009 L'Aquila Earthquake



Description: Figure plots the mean differences in population between qualified treatment municipalities and non-qualified control municipalities (black solid line) with 95% confidence intervals (blue short-dashed lines). The difference is centered at zero in 2008, the year before the earthquake. The black vertical line denotes the earthquake year. Source: authors' calculations and data from ISTAT [53].

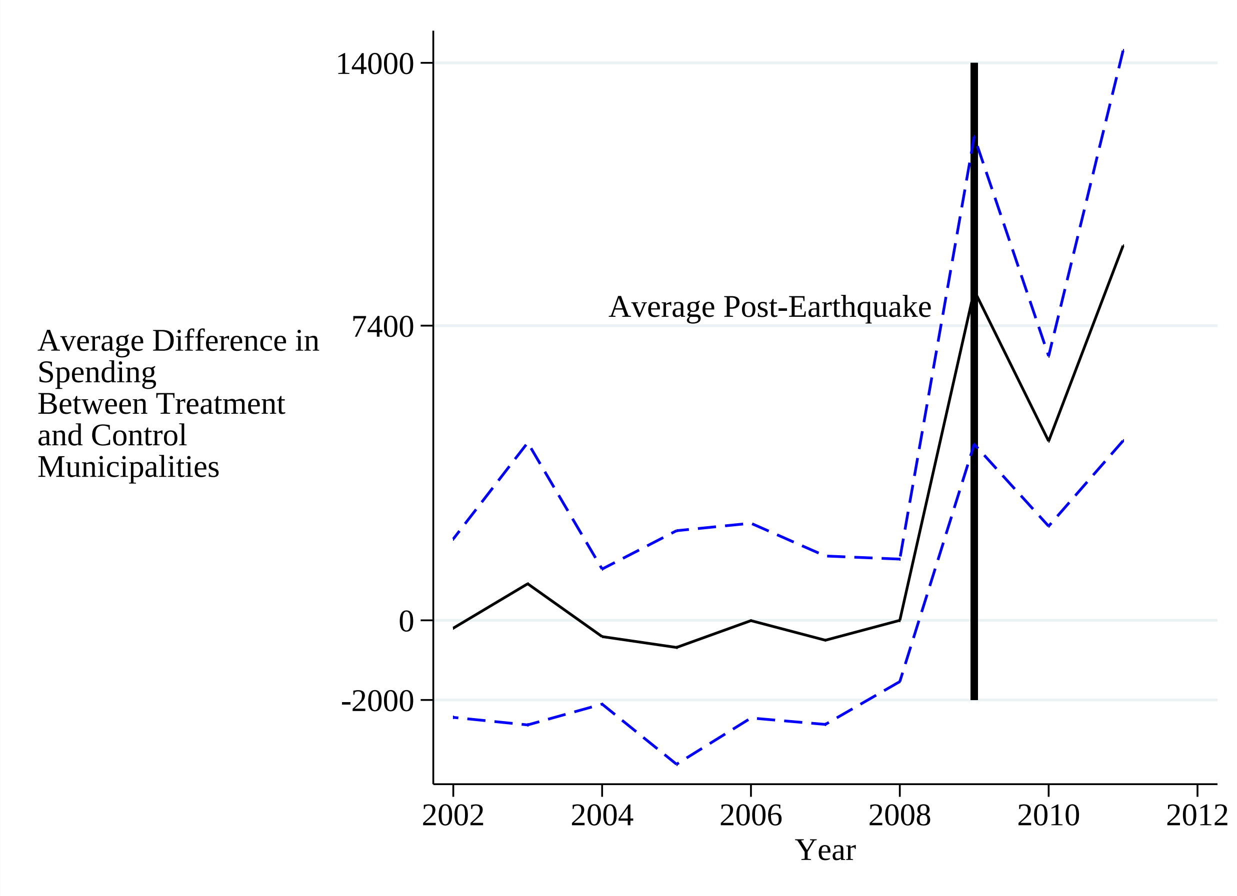
Interpretation: Before the 2009 L'Aquila earthquake, treatment and control municipalities had similar trends in population. There is no noticeable change in population between these municipalities after the earthquake, indicating that grants did not affect migration.

Figure 8: Trends for Night Lights Visible from Space Were Parallel Before and After the 2009 L'Aquila Earthquake



Description: Figure plots the mean differences in the luminosity of night lights visible from space between qualified treatment municipalities and non-qualified control municipalities (black solid line) with 95% confidence intervals (blue short-dashed lines). The difference is centered at zero in 2008, the year before the earthquake. The black vertical line denotes the earthquake year. Lights are measured on a scale of 0-10,000, with 10,000 being the brightest. Source: authors' calculations and data from the National Geophysical Data Center of the National Oceanic and Atmospheric Administration [68]. See Appendix D for more details.
Interpretation: Before the 2009 L'Aquila earthquake, treatment and control municipalities had similar trends in night lights. There is no noticeable change in night lights between these municipalities after the earthquake, indicating that grants did not increase night lights.

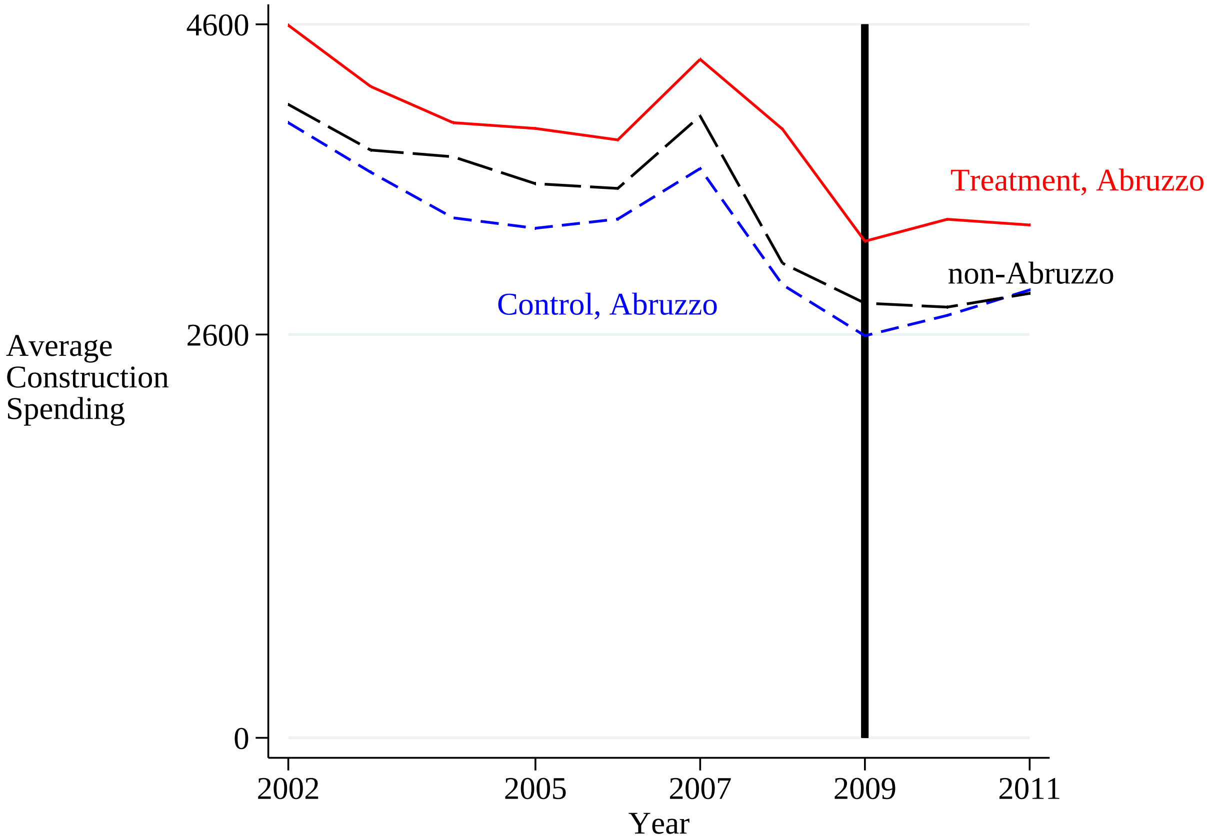
Figure 9: Government Spending Trends Were Parallel Before the 2009 L'Aquila Earthquake and Spending Increased for Treatment Municipalities Similarly to Grants After the Earthquake



Description: Figure plots the mean differences in municipal government spending, in real 2010 euro per-taxpayer, between qualified treatment municipalities and non-qualified control municipalities (black solid line) with 95% confidence intervals (blue short-dashed lines). The difference is centered at zero in 2008, the year before the earthquake. The black vertical line denotes the earthquake year. Source: authors' calculations and data from the Italian Ministry of Interior [33].

Interpretation: Before the 2009 L'Aquila earthquake, treatment and control municipalities had similar trends in government spending. The L'Aquila earthquake and subsequent "Decreto Legge 28 Aprile 2009, n.39" caused a large increase in government spending for treatment municipalities but not for control municipalities. On average, treatment municipalities increased spending by 7,400 euro per-taxpayer more than control municipalities after the L'Aquila earthquake (2009-2011). This higher spending closely tracked the increase in grants, which increased by 7,300 euro per-taxpayer after the earthquake (see figure 4).

Figure 10: No Jump in Construction in Abruzzo After the L'Aquila Earthquake



Description: Figure plots the average real per-taxpayer construction value added (euros) for qualified treatment municipalities in Abruzzo (red solid line), non-qualified control municipalities in Abruzzo (blue short-dashed line), and municipalities outside of Abruzzo in the regions of Basilicata, Campania, Molise, and Puglia (black long-dashed line). The black vertical line denotes the earthquake year. Source: authors' calculations using data from Osservatorio di Economia e Finanza [72].

Interpretation: Despite being damaged by the earthquake, there does not appear to be a jump in construction spending for either treatment or control municipalities in Abruzzo after the earthquake. Construction in neighboring regions exhibits a similar trend as Abruzzo, suggesting that construction spending in Abruzzo after the earthquake was not disproportionally financed by outside sources (e.g., outside aid or municipal self-financing).

10. Tables

Table 1: Grants did not increase personal income - Baseline results

	(1)	(2)	(3)	(4)	(5)
	OLS Income same-year	IV1st Income same-year	IV2nd Income same-year	IV2nd Income next-year	IV2nd Income 2-years later
$Grants_{i,t}$	-0.01		-0.04	0.00	0.02
	(0.01)		(0.06)	(0.06)	(0.06)
$MercalliThreshold_{i,t}$		4354.72			
		(1155.41)			
$Damages_{i,t}$	794.14	-363.84	887.89	988.91	731.97
	(499.84)	(2753.72)	(552.94)	(569.32)	(650.45)
$Distance_{i,t}$ (100s KM)	2197.49	-27901.92	890.78	1857.52	2318.38
	(1425.69)	(8545.65)	(2348.74)	(2587.62)	(3054.49)
$Distance^2_{i,t}$	-2061.06	21675.42	-1087.60	-1609.28	-1549.50
	(1094.58)	(6443.93)	(1774.93)	(1955.96)	(2319.91)
N	3027	3027	3027	2722	2421
Num. Muni.	305	305	305	305	305
F-test E_{it} (p-value)	0.04	0.00	0.05	0.14	0.43
F-stat 1st Stage			14.21	10.44	7.24

Description: Column 1 is the OLS regression of real per-taxpayer income (euros) on real per-taxpayer grants (euros). Column 2 is the first stage of our baseline IV model (1). The first stage is a regression of grants on our instrument $MercalliThreshold_{i,t}$, which is an indicator that takes a value of 1 for those municipalities ranked at or above Mercalli VI due to the L'Aquila earthquake starting in 2009. IV2nd refers to the second stage where the dependent variable is real per-taxpayer income in the same year (column 3), the next year (column 4), and two years later (column 5). $Distance_{i,t}$ is the distance of the municipality to the epicenter of the L'Aquila earthquake in 100s of kilometers and takes non-zero values starting in 2009. $Distance^2_{i,t}$ is the square of $Distance_{i,t}$. $Damages_{i,t}$, an index of AeDES damage levels, is shown in equation (3) and takes non-zero values starting in 2009. F-test E_{it} is the p-value for the joint two-sided test that the negative supply shock terms are zero. F-stat 1st Stage is the F-statistic on the excluded instrument in the 1st stage regression. Standard errors clustered by municipality are in parentheses. All columns include municipality and time fixed effects.

Interpretation: Controlling for the earthquake's negative supply shock and fixed effects, grants do not increase income for treatment municipalities relative to control municipalities in any year after the earthquake. This result confirms the event study of unconditional differences in income, shown in figure 5.

Table 2: Specifications with more controls show no increase in personal income

	(1) Additional Controls	(2) AeDES Dummies	(3) Damages Only	(4) Distance Only	(5) Mercalli V to VI-VII
$Grants_{i,t}$	-0.03	-0.02	-0.03	-0.01	-0.03
	(0.06)	(0.03)	(0.04)	(0.05)	(0.06)
$Damages_{i,t}$	986.31		810.75		1666.41
	(515.49)		(580.47)		(745.93)
$Distance_{i,t}$ ($100s$ KM)	1771.38			710.33	4563.88
	(2182.07)			(2321.40)	(4227.50)
$Distance^2_{i,t}$	-1762.71			-990.27	-4871.58
	(1648.52)			(1754.81)	(4136.95)
AeDES Dum/Interaction	No	Yes	No	No	No
Add. Controls	Yes	No	No	No	No
N	3027	3027	3027	3027	1218
Num. Muni.	305	305	305	305	122
F-test E_{it} (p-value)	0.02	0.01	0.16	0.06	0.13
F-stat 1^{st} Stage	16.20	16.11	15.15	20.68	15.33

Description: Table shows second-stage IV regressions where the dependent variable is real per-taxpayer declared personal income (euros) and the instrumented variable is real per-taxpayer grants (euros). Column 1 adds additional controls (casualties, population, the fraction of children (14 and younger), and the elderly (65 and older)). Column 2 uses individual AeDES levels instead of $Damages_{i,t}$, $Distance_{i,t}$, and $Distance^2_{i,t}$ to control for the earthquake's negative supply shock. Column 3 only uses $Damages_{i,t}$ and column 4 only uses $Distance_{i,t}$ and $Distance^2_{i,t}$ to control for the supply shock. Column 5 restricts the sample to municipalities ranked V to VI-VII, which are those nearest the grant threshold. $Distance_{i,t}$ is the distance of the municipality to the epicenter of the L'Aquila earthquake in 100s of kilometers and takes non-zero values starting in 2009. $Distance^2_{i,t}$ is the square of $Distance_{i,t}$. $Damages_{i,t}$, an index of AeDES damage levels, is shown in equation (3), and takes non-zero values starting in 2009. F-test E_{it} is the p-value for the joint two-sided test that the negative supply shock terms are zero. F-stat 1^{st} Stage is the F-statistic on the excluded instrument in the 1^{st} stage regression. Standard errors clustered by municipality are in parentheses. All columns include municipality and time fixed effects.

Interpretation: Adjusting controls or restricting the estimation sample to municipalities near the grant threshold leaves us with the same conclusion: disaster relief grants did not increase income.

Table 3: Grants also did not increase other economic outcomes: construction spending, population, or lights visible from space

	(1) Income	(2) Construction Value Added	(3) Population	(4) Lights
$Grants_{i,t}$	-0.04	0.03	-0.01	-0.03
	(0.06)	(0.05)	(0.01)	(0.02)
$Damages_{i,t}$	887.89	-35.50	100.55	166.32
	(552.94)	(302.74)	(211.59)	(193.48)
$Distance_{i,t}$ ($100s$ KM)	890.78	1598.98	314.69	-1130.92
	(2348.74)	(2711.84)	(750.36)	(990.74)
$Distance^2_{i,t}$	-1087.60	-820.07	-238.96	906.71
	(1774.93)	(1980.69)	(646.05)	(758.08)
N	3027	3027	3027	2436
Num. Muni.	305	305	305	305
F-test E_{it} (p-value)	0.05	0.13	0.93	0.46
F-stat 1^{st} Stage	14.21	14.21	14.21	13.94

Description: Table shows second-stage IV regressions where the instrumented variable is real per-taxpayer grants (euros). The dependent variables are same-year variables: real per-taxpayer personal income (euros, column 1), real per-taxpayer construction value added (euros, column 2), population (raw count as of December 31, column 3), and night lights (0-10,000 with 10,000 as brightest, column 4). $Distance_{i,t}$ is the distance of the municipality to the epicenter of the L'Aquila earthquake in 100s of kilometers and takes non-zero values starting in 2009. $Distance^2_{i,t}$ is the square of $Distance_{i,t}$. $Damages_{i,t}$, an index of AeDES damage levels, is shown in equation (3) and takes non-zero values starting in 2009. F-test E_{it} is the p-value for the joint two-sided test that the negative supply shock terms are zero. F-stat 1^{st} Stage is the F-statistic on the excluded instrument in the 1^{st} stage regression. Standard errors clustered by municipality are in parentheses. All columns include municipality and time fixed effects.

Interpretation: Disaster relief grants did not increase any of our other measures of economic activity (construction, population, or night lights visible from space) for treatment municipalities relative to control municipalities.

Table 4: Local public spending did not increase personal income

	(1) OLS Income same-year	(2) IV1st Income same-year	(3) IV2nd Income same-year	(4) IV2nd Income next-year	(5) IV2nd Income 2-years later
$Spending_{i,t}$	-0.00		-0.05	0.00	0.03
	(0.01)		(0.07)	(0.10)	(0.08)
$MercalliThreshold_{i,t}$		3554.37			
		(1253.07)			
$Damages_{i,t}$	780.44	-1832.50	813.49	987.60	716.90
	(491.38)	(3069.03)	(524.35)	(605.27)	(651.18)
$Distance_{i,t}$ ($100s\ KM$)	2260.97	-36929.43	203.88	1880.65	2560.48
	(1462.82)	(9642.69)	(3370.76)	(3740.10)	(3646.72)
$Distance^2_{i,t}$	-2109.72	27545.97	-608.31	-1626.33	-1724.22
	(1127.51)	(7239.35)	(2480.88)	(2802.15)	(2746.15)
N	3025	3025	3025	2722	2421
Num. Muni.	305	305	305	305	305
F-test E_{it} (p-value)	0.04	0.00	0.05	0.14	0.43
F-stat 1st Stage			8.05	4.44	4.69

Description: Column 1 is the OLS regression of real per-taxpayer income (euros) on real per-taxpayer municipial government spending (euros). Column 2 is the first stage of our baseline IV model (1), shown in equation (2), except with grants replaced with spending. The first stage is a regression of spending on our instrument $MercalliThreshold_{i,t}$, which is an indicator that takes a value of 1 for those municipalities ranked at or above Mercalli VI due to the L'Aquila earthquake starting in 2009. IV2nd refers to the second stage where the dependent variable is real per-taxpayer income in the same year (column 3), the next year (column 4), and two years later (column 5). $Distance_{i,t}$ is the distance of the municipality to the epicenter of the L'Aquila earthquake in 100s of kilometers and takes non-zero values starting in 2009. $Distance^2_{i,t}$ is the square of $Distance_{i,t}$. $Damages_{i,t}$, an index of AeDES damage levels, is shown in equation (3) and takes non-zero values starting in 2009. F-test E_{it} is the p-value for the joint two-sided test that the negative supply shock terms are zero. F-stat 1st Stage is the F-statistic on the excluded instrument in the 1st stage regression. Standard errors clustered by municipality are in parentheses. All columns include municipality and time fixed effects.

Interpretation: Instrumenting spending with $MercalliThreshold_{i,t}$, which recovers the multiplier of spending on income as opposed to grants on income, does not change our inference: we find a disaster relief multiplier of zero.

Table 5: Geographic donut regressions show no effect of grants on income

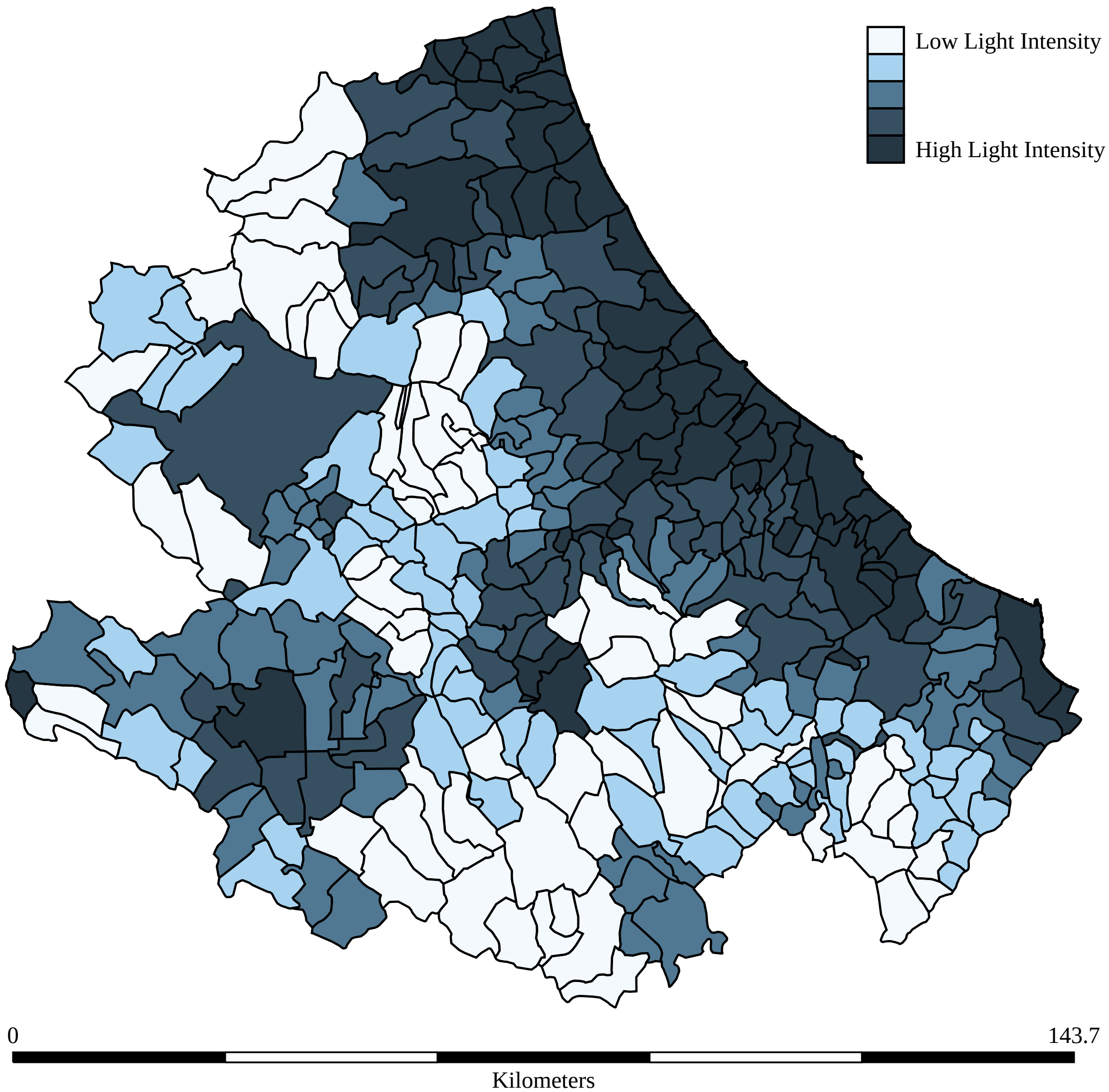
	(1) OLS non-Border Muni.	(2) IV1st non-Border Muni.	(3) IV2nd non-Border Muni.	(4) OLS Border Muni.	(5) IV1st Border Muni.	(6) IV2nd Border Muni.
$Grants_{i,t}$	-0.00		-0.03	-0.01		-0.02
	(0.01)		(0.04)	(0.02)		(0.07)
$MercalliThreshold_{i,t}$		12737.83			4396.26	
		(5187.43)			(1244.44)	
$Damages_{i,t}$	240.93	-3033.59	747.80	791.49	3022.42	872.97
	(253.61)	(6864.83)	(623.26)	(563.62)	(2267.93)	(839.17)
N	2209	2209	2209	818	818	818
Num. Muni.	223	223	223	82	82	82
F-stat 1st Stage			6.03			12.48

Description: Columns 1 - 3 exclude municipalities that border a municipality with the opposite treatment assignment. Columns 4 - 6 only use these excluded municipalities. Columns 1 and 4 are OLS regressions of real per-taxpayer income (euros) on real per-taxpayer grants (euros). Columns 2 and 5 are the first stage of our baseline IV model (1), shown in equation (2). The first stage is a regression of grants on our instrument $MercalliThreshold_{i,t}$, which is an indicator that takes a value of 1 for those municipalities ranked at or above Mercalli VI due to the L'Aquila earthquake starting in 2009. IV2nd refers to the second stage where the dependent variable is real per-taxpayer income in the same year. $Damages_{i,t}$, an index of AeDES damage levels, is shown in equation (3) and takes non-zero values starting in 2009. F-stat 1st Stage is the F-statistic on the excluded instrument in the 1st stage regression. Standard errors clustered by municipality are in parentheses. All columns include municipality and time fixed effects.

Interpretation: The disaster relief multiplier for municipalities that do not border a municipality with the opposite treatment assignment (which, by definition, are geographically separated) is similar to the multiplier among those municipalities that do border a municipality with the opposite treatment assignment. Both samples indicate no effect of grants on income.

Appendix A. Additional Tables and Figures

Figure A.11: Night Lights Density in 2007



Description: Map of the Abruzzo region's municipalities. Web Mercator projection. Colors correspond to the average of night lights for 2007, divided into quintiles. Darker colors indicate more light. Source: authors' calculations and data from the National Geophysical Data Center of the National Oceanic and Atmospheric Administration [68]. See Appendix D for more details.

Table A.6: Percentage of Buildings in Each AeDES Category by Building Type

	Type of building						
AeDES category	Private	Public	Hospitals	Barracks	Schools	Factories	**Overall**
A	55.0	57.5	51.5	71.0	52.9	56.6	**55.2**
B	15.6	19.1	18.2	25.0	26.7	19.4	**16.5**
C	3.3	4.5	15.2	3.0	2.4	4.5	**3.4**
D	1.9	3.4	3.0	-	3.7	0.8	**1.9**
E	21.5	14.3	12.1	1.0	12.5	15.7	**20.4**
F	2.7	1.2	-	-	1.8	3.0	**2.6**
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Description: Table shows the distribution of damages across types of buildings in the affected areas using the AeDES classification system. This system categorizes civil structures after a seismic event on six levels ranging from "A" ("usable building") to "F" ("unusable building and severe external risks"). For details about the AeDES system, see Baggio, Bernardini, Colozza, Corazza, Della Bella, Di Pasquale, Dolce, Goretti, Martinelli, Orsini, Papa, and Zuccaro [7]. Source: Civil Protection Department, Italian Ministry of Interior [27].

Table A.7: Distribution of Mercalli Ranks Across Provinces in Abruzzo in 2009

Mercalli rank	Chieti	L'Aquila	Pescara	Teramo	**Total**
0	99	31	18	27	**175**
V	4	25	15	8	**52**
V-VI	1	10	6	4	**21**
VI	0	28	7	8	**43**
VI-VII	0	6	0	0	**6**
VII	0	3	0	0	**3**
VII-VIII	0	1	0	0	**1**
VIII	0	0	0	0	**0**
VIII-IX	0	2	0	0	**2**
IX	0	2	0	0	**2**
Total	**104**	**108**	**46**	**47**	**305**

Source: INGV database [66].

Table A.8: Distribution of Mercalli Ranks in Abruzzo Across Years

Mercalli	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	**Total**
0	136	160	172	246	247	305	305	175	305	305	**2,356**
I	3	96	82	58	48	0	0	0	0	0	**287**
II	3	10	8	1	1	0	0	0	0	0	**23**
II-III	4	6	3	0	0	0	0	0	0	0	**13**
III	10	10	4	0	5	0	0	0	0	0	**29**
III-IV	29	16	12	0	3	0	0	0	0	0	**60**
IV	44	2	9	0	1	0	0	0	0	0	**56**
IV-V	54	4	10	0	0	0	0	0	0	0	**68**
V	22	1	4	0	0	0	0	52	0	0	**79**
V-VI	0	0	1	0	0	0	0	21	0	0	**22**
VI	0	0	0	0	0	0	0	43	0	0	**43**
VI-VII	0	0	0	0	0	0	0	6	0	0	**6**
VII	0	0	0	0	0	0	0	3	0	0	**3**
VII-VIII	0	0	0	0	0	0	0	1	0	0	**1**
VIII	0	0	0	0	0	0	0	0	0	0	**0**
VIII-IX	0	0	0	0	0	0	0	2	0	0	**2**
IX	0	0	0	0	0	0	0	2	0	0	**2**
Total	**305**	**305**	**305**	**305**	**305**	**305**	**305**	**305**	**305**	**305**	**3,050**

Description: Mercalli ranks before 2009 refer to the following events: "Subappennino Dauno" (November 1^{st}, 2002, magnitude 5.72, epicenter in Molise region), "Zona Ascoli Piceno" (May 25^{th}, 2003, magnitude 4.30, epicenter in Marche region), "Molise" (June 1^{st}, 2003, magnitude 4.66, epicenter in Molise region), "Monti dei Frentani" (December 30^{th}, 2003, magnitude 4.63, epicenter in Molise region), "Monti Tiburtini" (October 5^{th}, 2004, magnitude 4.05, epicenter in Lazio region), "Zona Teramo" (December 9^{th}, 2004, magnitude 4.54, epicenter in Abruzzo region), "Monti dei Frentani" (March 1^{st}, 2005, magnitude 4.24, epicenter Marche region), "Maceratese" (April 12^{th}, 2005, magnitude 4.24, epicenter in Marche region), "Valle del Topino" (December 15^{th}, 2005, magnitude 4.69, epicenter in Marche region), "Maceratese" (April 10^{th}, 2006, magnitude 4.55, epicenter Marche region), and "Promontorio del Gargano" (May 29^{th}, 2006, magnitude 4.92, epicenter in Puglia region).

Appendix B. Mercalli Scale

The Richter scale (or simply "magnitude") was invented by Charles Francis Richter at the California Institute of Technology. It quantifies the energy released during an earthquake on a base-10 logarithmic scale. For instance, an earthquake that measures 5.0 on the Richter scale has a shaking amplitude 10 times larger than one that measures 4.0 and corresponds to a release of energy that is 31.6 times larger. Technically, the magnitude is defined as the logarithm of the ratio of the amplitude of waves measured by a seismograph to an arbitrary small amplitude. However, before seismologists were able to measure the moment-magnitude of earthquakes, other scales were invented to categorize seismic episodes. In 1783 an Italian architect (Pompeo Schiantarelli) invented a rudimentary scale to classify the affected regions according to the severity of the damages. The scale underwent several revisions, and it is now known as the Mercalli scale, from the Italian volcanologist Giuseppe Mercalli who modified it in 1902. The scale is a narrative description of the damages defined on twelve ranks ranging from "instrumental" (I) to "catastrophic" (XII). Below we report the definitions of each rank.

- **I Instrumental** *People:* Not felt except by very few people under exceptionally favorable circumstances.
- **II Weak** *People:* Felt by persons at rest, on upper floors, or those favorably placed.
- **III Slight** *People:* Felt indoors; hanging objects may swing, vibration similar to passing of light trucks, duration may be estimated, may not be recognized as an earthquake.
- **IV Moderate** *People:* Generally noticed indoors but not outside. Light sleepers may be awakened. Vibration may be likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building. *Fittings:* Doors and windows

rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock. *Structures:* Walls and frames of buildings, and partitions and suspended ceilings in commercial buildings, may be heard to creak.

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

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

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

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

- **IX Violent** *Structures:* Many Type I buildings destroyed. Type II buildings heavily damaged, some collapse. Type III buildings damaged, some with partial collapse. Type IV structures damaged in some cases, some with flexible frames seriously damaged. Damage or permanent distortion to some Type V structures. Houses shifted off unsecured foundations. Brick veneers fall and expose frames. *Environment:* Cracking of ground conspicuous. General land sliding on steep slopes. Liquefaction effects intensified and more widespread, with large lateral spreading and flow sliding adjacent to streams, canals, lakes, etc.

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

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

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

Construction types. *Type I Buildings:* Buildings with low standard of workmanship, poor mortar, or constructed of weak materials like mud brick or rammed earth. Soft story structures (e.g. shops) made of masonry, weak reinforced concrete or composite materials (e.g. some walls timber, some brick) not well tied together. Masonry buildings otherwise conforming to Types I to III buildings, but also having heavy unreinforced masonry towers. (Buildings constructed entirely of timber must be of extremely low quality to be Type I). *Type II Buildings:* Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the corners, but neither designed nor reinforced to resist lateral forces. Buildings with no heavy reinforced masonry towers. *Type*

III Buildings: Reinforced masonry or concrete buildings of good workmanship and with sound mortar, but not formally designed to resist earthquake forces. *Type IV Structures:* Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special collapse or damage limiting measures taken (mid-1930s to c. 1970 for concrete and to c. 1980 for other materials). *Type V Structures:* Buildings and bridges, designed and built to normal use standards, i.e. no special damage limiting measures taken, other than code requirements, dating since c. 1970 for concrete and c. 1980 for other materials. *Type VI Structures:* Structures, dating from c. 1980, with well-defined foundation behavior, that have been specially designed for minimal damage, e.g., seismically isolated emergency facilities, some structures with dangerous or high contents, or new generation low-damage structures. **Windows.** *Type I:* Large display windows, especially shop windows. *Type II:* Ordinary sash or casement windows. **Water tanks.** *Type I:* External, stand-mounted, corrugated iron tanks. *Type II:* Domestic hot-water cylinders unrestrained except by supply and delivery pipes.

Appendix C. Translating Personal Income Multiplier to Gross Regional Output Multiplier

Our main measure of economic activity—personal declared income for tax purposes—provides, in our opinion, the best measure of municipal-level economic activity in Italy. That said, personal declared income is only a portion of gross regional output (at the national level, gross domestic product (GDP)).

In order to provide an approximation to gross regional output multipliers based on our estimated personal income multipliers, we follow the scaling methodology proposed in Section III of Chodorow-Reich [25] but modified to our context. Whereas Chodorow-Reich [25] scales the effects of government expenditures on employment to effects on gross regional output, we are scaling effects on personal income to effects on gross regional output. As such, our setup is identical to Chodorow-Reich [25] except for the fact that our measure already captures variation in hours and does not require scaling by the hours-employment elasticity.

Our baseline results provide estimates of the causal effect of municipal government expenditures (exp_{it}) on income (inc_{it}), denoted by β^{INC} in the equation (C.1), where ∂ is the partial derivative:

$$\partial inc_{it} = \beta^{INC} \partial exp_{it} \tag{C.1}$$

For comparison to (some) other literature, we are instead interested in β^{GDP}, the similarly defined effect of exp_{it} on the municipal-level analog of GDP. This effect can be rewritten as a function of our income multiplier estimate, β^{INC}, and the relationship between income and GDP under the assumptions that the elasticity between personal income and the municipal-level analog of GDP is unaffected by the L'Aquila earthquake and that this elasticity is similar at the national level as in Abruzzo:

$$\begin{aligned}
\beta^{GDP} &= \frac{\partial gdp_{it}}{\partial exp_{it}} \\
&= \frac{\partial gdp_{it}}{\partial exp_{it}} * \frac{\partial inc_{it}}{\partial inc_{it}} \\
&= \frac{\partial gdp_{it}}{\partial inc_{it}} * \frac{\partial inc_{it}}{\partial exp_{it}} \\
&= \zeta * \beta^{INC}
\end{aligned} \tag{C.2}$$

where ζ captures the comovement between real GDP and real personal declared income. Inferring ζ using national-level data, $\zeta \approx 1.6$.[35] Therefore, applying this scaling factor of 1.6 to our personal income multiplier estimates in table 1, we can reject gross regional output multipliers of one up through two years after the earthquake.

[35] Calculated using the average of changes in non-seasonally-adjusted quarterly estimates of real national-level wages and salaries and real GDP over 2002-2011 using data from Eurostat [40].

Appendix D. Night Lights Data

The night lights data from the National Oceanic and Atmospheric Administration, National Centers for Environmental Information [68] are derived from images taken by orbiting satellites from the United States Air Force's Defense Meteorological Satellite Program (DMSP) that have a ground sample distance of 0.56 kilometers that are then smoothed into 5x5 blocks by onboard systems [39].

The National Oceanic and Atmospheric Administration takes the raw satellite orbit data and then uses orbits that occurred between 20:30 and 22:00 local time. They then exclude orbits obscured by clouds, remove transitory anthropogenic light (such as fires and gas flares), and remove most natural light (such as lunar light, solar glare, and the auroras) [39]. The remaining processed orbits are then averaged to give satellite-year estimates of "stable" anthropogenic light at night.

The data distributed to the public from these averages of qualified orbits come in the form of satellite-specific annual 256 bit per pixel images of the Earth's surface. The Earth images cover -65 to +75 degrees latitude and -180 to +180 degrees longitude. Each pixel in the Earth images is 30 arc seconds ($1/120^{th}$ of a degree) by 30 arc seconds, so each image contains over 725,000,000 pixels. In Abruzzo, this pixel size corresponds to a surface area of approximately 0.64 square kilometers.[36]

Light in the public images is recorded as a digital number that ranges from 0 to 63. The digital number is not exactly proportional to the true visible amount of stable light (radiance) recorded by the satellites due to a combination of satellite sensor gain and processing by the National Oceanic and Atmospheric Administration, though higher values indicate more light.

[36] Because each pixel is a fixed size in arc seconds and due to the curvature of the Earth, the pixels correspond to different sizes in terms of surface area depending on their latitude. Pixels near the equator represent a larger surface area than pixels near the poles. That said, because Abruzzo only spans approximately 1.2 degrees latitude, the pixels within Abruzzo are approximately the same surface area.

We use these publicly available "Average Visible, Stable Lights, and Cloud Free" images taken from two satellites: F16 for the years 2004 to 2009 and F18 for 2010 and 2011. In order to reduce the possibility of measurement errors when switching across satellites, we do not consider data before 2004.

Because the lights data are measured at fixed arc second intervals and because municipal borders are defined on a more refined scale than 30 arc second intervals, the light pixels do not correspond neatly with municipal borders. Therefore, a light pixel may cover more than one municipality. In our reported results, we calculate average luminosities by assigning the municipality for each light pixel according to pixel midpoints, measured in degrees. We also check our results using only light pixels that do not contain a municipal border, which gives very similar results to using pixel midpoints (the correlation of average light between these two methods of assigning light pixels to municipalities is > 0.99 in each year). We determine the municipality of each pixel using the ray casting algorithm implemented by Picard [74]. Figure A.11 in Appendix A shows the average luminosity at night in 2007 for the municipalities in our sample. The raw data are measured from 0 to 63 with 63 as the brightest, but we scale to 0 to 10,000 for easier interpretation of the lights coefficients.