ISSN 2385-2755
DiSSE Working papers
[online]

SAPIENZA
UNIVERSITÀ DI ROMA

WORKING PAPERS SERIES
DIPARTIMENTO DI
SCIENZE SOCIALI ED ECONOMICHE

Environmental Risk Salience and Real Estate Markets

Marco Letta Samuel Nocito

N. 02/2026

SAPIENZA - UNIVERSITY OF ROME
P.le Aldo Moro n.5 – 00185 Roma T(+39) 0649910563
CF80209930587 – P.IVA 02133771002

Environmental Risk Salience and Real Estate Markets*

Marco Letta[†] Samuel Nocito[‡]

July, 2026

Abstract

When do risks become real to economic agents? Many environmental hazards are publicly known long before they cause damage, yet remain latent in household decisions and market prices. We study whether risk salience itself can move markets when the underlying risk is long-standing and no disaster has occurred. Our setting is the Phlegraean Fields near Naples, Italy, where a long-known volcanic and seismic hazard became highly salient during the bradyseismic crisis that began in 2023. Despite minor physical damage, no fatalities, and no upward revision of official risk, the crisis reshaped local real estate markets. We document a sharp divergence between ownership and rental markets: sale prices fall in the most exposed ownership market, while rents rise as households adjust along tenure and spatial margins. Complementary demand and supply evidence supports this interpretation. We also show that both direct physical experience and media salience matter, with media attention amplifying and extending the effects of local seismic perceptibility. Our findings suggest that markets respond not only to risk itself, but also to attention to risk.

Keywords: environmental risk; risk salience; housing markets; natural experiment.
JEL Classification: D84, H12, Q54, R31.

*First Version: September 3, 2025. We are grateful to Giuseppe Spataro for excellent research assistance. We are grateful to *Immobiliare.it Insights* for kindly providing demand and supply data, and especially to Lorenzo Mastore for his assistance with data use and variable definitions. We thank Guglielmo Barone, Augusto Cerqua, Sergio Galletta, Giorgio Gulino, Joanna Kopinska, Giovanni Mastrobuoni, Paolo Pinotti, Andrea Prat, Gabriele Pinto, Francesco Sobbrio, Federico Zampollo, and participants at a seminar in Sapienza University of Rome and at the COunterfactual Methods for Policy Impact Evaluation conference in Paris (COMPIE, 2026) for helpful comments and discussions. A previous version of the paper circulated under the title "Disaster Risk, Public Salience, and Real Estate Markets: Evidence from the Phlegraean Fields". The usual disclaimers apply.
†Sapienza University of Rome, marco.letta@uniroma1.it
‡Sapienza University of Rome, CESifo & IZA, samuel.nocito@uniroma1.it

"*Nothing ever becomes real till it is experienced.*"

– John Keats, Letter to George and Georgiana Keats, 1819

1 Introduction

Many environmental risks are publicly known long before they cause damage. Flood maps, seismic classifications, emergency plans, and scientific monitoring make information available, yet the associated risks may remain weakly reflected in everyday decisions. In principle, markets should react when new information changes fundamentals. But known risks can also become vivid without a disaster or a clear, sudden change in measured objective-risk indicators. Public concern about earthquakes affecting New York City in 2011 and 2024, California's "Big One," or the Yellowstone supervolcano reflects the same logic: familiar risks can become salient before any disaster occurs. This creates a distinction between *awareness* and *salience*: households may know that a hazard exists without treating it as sufficiently immediate or vivid to alter behavior, consistent with the availability heuristic of Tversky and Kahneman (1973, 1974). The question is therefore not only whether households are aware of environmental risk, but whether attention to that risk is strong enough to change behavior and move markets.

This distinction matters because information, attention, and fundamentals need not move together. Known risks may remain economically latent until attention makes them decision-relevant. If markets respond only to changes in risk fundamentals, renewed attention to already-known hazards should have limited effects. If instead attention affects decisions even when risk is already part of the information environment, then salience becomes an economically relevant margin: it determines when known risks become capitalized into prices, reflected in behavior, and real to economic agents. Our focus is this margin in the economics of risk: the conversion of known risk into salient risk, and of salient risk into priced economic risk.

We investigate this idea in the Phlegraean Fields (*Campi Flegrei*), a large volcanic caldera near Naples, Italy. The area is home to more than one million residents, creating a highly unusual setting in which a very large population lives atop an active volcanic caldera. It is characterized by bradyseism, a distinctive manifestation of volcanic unrest involving cyclic ground uplift, often accompanied by shallow seismic activity perceptible to the population. In September 2023, a sequence of strongly felt earthquakes initiated an ongoing bradyseismic crisis. The crisis sharply increased public attention and even international media coverage (CNN, 2023; The Washington Post, 2024; BBC, 2024; The New York Times, 2024; The Guardian, 2025), but it produced no fatalities, no catastrophic destruction, and no upward revision of the official alert level.

Housing markets provide a particularly informative setting in which to study this shock: housing is both a consumption good and a long-lived asset, so beliefs about persistent local exposure are capitalized into sale prices, while rents capture a more flexible margin of residential adjustment. In the hedonic tradition, these outcomes provide revealed-preference evidence on how households value local amenities and disamenities, including environmental risk (Rosen, 1974; Roback, 1982; Chay and Greenstone, 2005).[1]

The setting is unusual because the hazard itself was not newly discovered. Bradyseism in the Phlegraean Fields has been documented for centuries and systematically monitored for decades. The 1982–84 crisis led to the evacuation and temporary relocation of roughly 30,000 residents of *Pozzuoli* and remains central to local memory. The main volcanic emergency zones and seismic-risk classifications were also in place well before 2023. After the May 2024 seismic sequence, the Italian Minister for Civil Protection explicitly stated that residents knew the risks associated with living in the area (ANSA, 2024). Survey evidence and the institutional record similarly show that the hazard was part of the local information environment, even if it was not a dominant concern in ordinary times. These facts establish that awareness of the hazard predated the current crisis, while its relevance in everyday decisions remained limited.

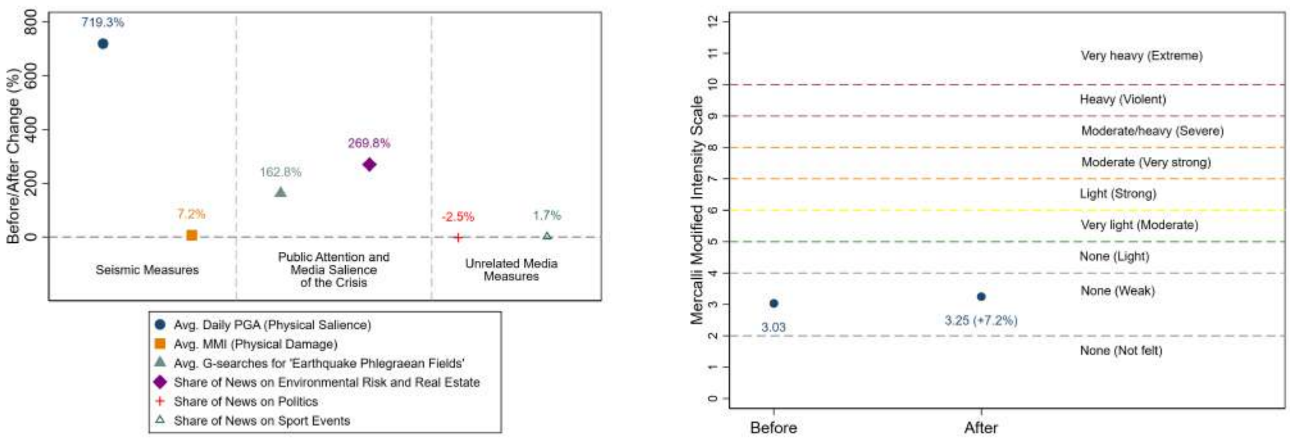
A separate and crucial requirement for our design is that the post-2023 shock increased salience without operating through catastrophe, substantial physical damage, or a damage-based revelation of new risk. Figure 1 provides direct evidence on this point. Average daily Peak Ground Acceleration (PGA), which captures local seismic perceptibility, increased by 719% after the onset of the crisis. Google searches for "Earthquake Phlegraean Fields" increased by 162.8%, and the

[1]We use *environmental risk* as a broad umbrella term for place-based risks arising from natural and environmental hazards, including volcanic, seismic, hydrological, climatic, and other environmental exposures. In our empirical setting, the relevant environmental risk is the volcanic and seismic hazard associated with bradyseism.

share of news jointly mentioning environmental risk and real estate rose by 269.8%. By contrast, average Modified Mercalli Intensity (MMI) increased by only 7% and remained within the "None" damage category, while unrelated news about politics and sports showed virtually no change.[2] The figure therefore documents the central identifying contrast of the paper: a large change in salience and attention with no comparable discrete change in underlying risk fundamentals.[3]

Figure 1: Phlegraean Fields - Descriptive Evidence on Salience and Damage

(a) Environmental Risk Salience (b) Negligible Physical Damage



Notes: This figure reports descriptive before-after changes in salience and damage-related measures for treated municipalities in the Phlegraean Fields. Panel (a) reports percentage changes in physical seismic salience, media salience of the crisis, and unrelated media measures after the onset of the bradyseismic escalation period relative to the pre-period. Physical seismic salience is measured by average daily peak ground acceleration (PGA), while physical damage is proxied by average Modified Mercalli Intensity (MMI). Public attention is measured by Google searches for "Earthquake Phlegraean Fields" and media salience by the share of news articles jointly mentioning environmental risk and real estate; unrelated media measures include the share of news on politics and the share of news on sport events. Panel (b) reports average MMI before and after the onset of the bradyseismic escalation period. The MMI categories shown in the panel report expected damage levels, with the corresponding ground-shaking intensity reported in parentheses. See Figure OA.1 for a detailed description of the INGV MMI scale, and Figure OA.21 for before/after normalized changes in other seismic and media measures.

A natural concern is that the crisis changed the information environment. We agree. We do not claim that households received no new information, nor that subjective beliefs were unchanged. The earthquake sequence, media coverage, inspections, and policy measures all provided signals that could affect perceived risk. The distinction we draw is not between information and no infor-

[2] Appendix Figure OA.21 reports normalized before-after changes, calculated as $(X_t - X_{t-1})/(X_t + X_{t-1})$, yielding values bounded in $[-1, 1]$. It replicates Figure 1 with normalized changes and extends it to other seismic and media-related measures.

[3] Appendix Figure OA.2 shows that Google searches in Campania for earthquake- and eruption-related queries about the Phlegraean Fields rose sharply and persistently during the crisis. The largest peaks coincide with the main high-salience seismic sequences in September–October 2023, May 2024, and March 2025, documented in Appendix Table OA.1. Search activity was low but not zero before the crisis, consistent with pre-existing awareness; the post-2023 change is one of scale and persistence.

mation, but between changes in risk salience, attention, and subjective probabilities, on the one hand, and abrupt changes in measured objective risk, on the other. The 2023 crisis made a long-known hazard more immediate and difficult to ignore, but it did not coincide with catastrophic destruction or the discovery of a new hazard. The shock was therefore not primarily a discrete break in measured risk conditions, but a change in risk salience and, in turn, in attention to the hazard. Our setting thus allows us to study a transition from awareness to acute perceived relevance, rather than a transition from unawareness to awareness. We also show that policy-measure salience does not drive the results, supporting this interpretation. This distinction separates our analysis from the destruction and reconstruction channels that dominate post-disaster settings.

We combine semiannual administrative data from the Italian Real Estate Market Observatory (OMI) with official volcanic-risk zones and municipality-level demographic and seismic characteristics, constructing a 2020–2025 municipality–residential-tier panel for both sale and rental markets. We consider three nested treatment definitions—the Intervention, Red, and Emergency Zones—and define treatment as beginning in the second semester of 2023. We estimate event-study and static difference-in-differences specifications using a refined group of Southern Italian municipalities comparable in population and seismic risk, and complement the baseline design with synthetic difference-in-differences, sensitivity analyses following Rambachan and Roth (2023), and randomization-inference placebo tests.

Our main finding is a sharp divergence between ownership and rental markets. In the Intervention Zone—the area most directly exposed to the bradyseismic crisis—sale prices fall immediately and remain persistently below their pre-crisis level, reaching approximately €60 per square meter by the end of the sample, about 3.3% relative to the last pre-crisis semester. Sale prices do not display comparable declines in the broader Red and Emergency Zones. Rental prices, by contrast, rise across all three treatment definitions: in the Intervention Zone, rents increase by approximately €0.40 per square meter in the first post-treatment semester and by about €0.62 by the end of the sample, corresponding to increases of roughly 7% and 11%. The pattern is reproduced by static and synthetic difference-in-differences estimates and is robust to deviations from parallel trends and randomization-inference exercises.

We next examine the distinct roles of direct physical experience and media attention.[4] Stronger contemporaneous physical salience is associated with larger sale-price declines in the Intervention and Red Zones, while lagged media salience, residualized with respect to local physical intensity, predicts stronger subsequent sale-price reductions across all treatment definitions. For rents, the physical- and media-salience interactions are small and statistically insignificant, suggesting that the generalized rental increase reflects broader tenure and spatial adjustment rather than mechanically higher demand where salience is highest.

We then develop a simple dynamic model to rationalize the ownership–rental divergence through the joint operation of tenure and spatial adjustment. When a known hazard becomes vivid, some households may delay purchasing or require greater compensation to hold housing wealth in exposed locations. Households tied to local labor markets, schools, or family networks may remain nearby but rent for longer; others may move toward locations perceived as safer. With relatively inelastic short-run rental supply, both responses can raise rents even as ownership values fall in the most exposed market.

Finally, we provide empirical evidence consistent with these mechanisms. Using data from *Immobiliare.it*, Italy's largest real-estate search portal, we show that ownership demand weakens most in the Intervention Zone, rental search pressure rises, and fresh listing inflows do not change. Formal registrations from other municipalities decline and cancellations increase in the most affected municipalities, while external survey evidence supports the model's assumptions on local attachment, tenure transitions, and limited insurance coverage. Within the Intervention Zone, peripheral and suburban areas experience the largest sale-price declines, while some central and semi-central segments display relative resilience or appreciation. Outside the Phlegraean risk zones, rental spillovers extend to nearby markets that retain proximity to jobs and family networks, whereas sale-price spillovers are concentrated in destinations with lower baseline risk.

A substantial body of research has documented that environmental risk is incorporated into property prices, particularly in settings involving long-run exposure to natural hazards and the aftermath of severe events (e.g., Bernstein *et al.* (2019); Bin and Landry (2013); Boustan *et al.*

[4]In our setting, direct physical experience refers to locally perceptible seismic activity, while media attention captures geographically targeted news coverage of environmental risk and real estate.

(2020); Ikefuji *et al.* (2022); Hallstrom and Smith (2005); Hidano *et al.* (2015); Keys and Mulder (2024); Naoi *et al.* (2009); Roth Tran and Wilson (2025); Zhao *et al.* (2025)). A common finding is that exposed property values decline after disasters, changes in the pricing of disaster risk, or other risk-revealing shocks, although some studies also document price or rent increases after severe events, consistent with broader equilibrium adjustments in local housing markets (Deryugina *et al.*, 2018). A separate literature uses individual survey or experimental data to study how major disasters affect risk preferences and related behavioral responses, offering contrasting evidence on whether exposure increases or decreases risk tolerance (Beine *et al.*, 2025; Cameron and Shah, 2015; Gao *et al.*, 2020; Hanaoka *et al.*, 2018). These two bodies of literature have thus far evolved along separate paths and have remained largely disconnected.

A related yet distinct strand of research—closest to our paper—examines risk salience, understood as the prominence or visibility of natural-hazard exposure generated by direct experience or heightened attention.[5] Several studies focus on first-hand experience. Wildfire visibility generates immediate but short-lived housing-market responses in high-risk areas of Colorado (McCoy and Walsh, 2018), while a catastrophic quick-clay landslide in Norway made mapped risk more prominent and reduced prices in exposed areas (Dugstad and Sommervoll, 2026). Wastewater-injection-induced seismicity similarly affects housing values in Oklahoma (Ferreira *et al.*, 2018; Metz *et al.*, 2017). In the United Kingdom, Gibbons *et al.* (2021) find that licensing areas for shale-gas exploration did not affect house prices, whereas drilling the first well—which caused two minor earthquakes—did. Koster and Van Ommeren (2015) likewise document persistent house-price effects from perceptible earthquakes induced by natural-gas extraction in the Netherlands.

Media coverage and public communication provide a second route through which risk becomes salient. A broader media-economics literature shows that prominence in the information environment can shape economic and political behavior and amplify the consequences of underlying events (Strömberg, 2004; Eisensee and Strömberg, 2007; Besley *et al.*, 2026). In environmental and housing-market settings, Ando *et al.* (2017) find no measurable response of Swedish housing

[5] More broadly, the economics literature shows that the salience of policies and high-profile events independently shapes behavior (Chetty *et al.*, 2009; Dessaint and Matray, 2017; Frydman and Wang, 2020; Gulino and Masera, 2023; Nardotto and Sequeira, 2026), including risk attitudes and preferences (Bordalo *et al.*, 2012).

prices near domestic nuclear plants to news coverage of the Fukushima disaster. By contrast, Agarwal *et al.* (2025) document large real-estate responses following the Singapore prime minister's announcement identifying areas vulnerable to sea-level rise. Related work also considers whether the names assigned to disasters affect perceived severity and behavior, with mixed findings (Christensen and Christensen, 2014; Jung *et al.*, 2014; Malter, 2014; Baiocchetti *et al.*, 2025).

The closest existing studies nevertheless differ from ours along a central dimension. They generally examine settings in which salience follows a realized disaster, an emerging hazard, a newly experienced shock, or a disclosure that makes exposure newly prominent.[6] In much of the literature, however, attention is difficult to isolate because salience often rises together with new disclosure, substantial physical damage, or catastrophe. Our setting is different: salience arises locally, through direct physical experience, media coverage, and policy visibility around a familiar hazard, without a realized disaster, formal risk reclassification, or the discovery of a new hazard. Our central contribution is therefore to show that environmental risk salience itself can change economic behavior and market prices.

These findings have implications for risk communication and preparedness policy. Information is not absorbed continuously: the timing and credibility of public communication may affect behavior even when the underlying hazard is already known. Our findings show that attention to known risk is an economically consequential margin that can reprice assets and redistribute housing demand before physical damage occurs. They do not imply that greater salience is necessarily welfare-improving; rather, they highlight the importance of pairing credible risk communication with housing and relocation policies that make protective adjustment feasible and orderly.

The remainder of the paper is organized as follows. Section 2 provides background information on the Phlegraean Fields. Section 3 presents the data and descriptive evidence. Section 4 outlines the empirical strategy. Section 5 reports the main findings. Section 6 focuses on interpretation and underlying mechanisms. Section 7 discusses policy implications and concludes.

[6] McCoy and Walsh (2018) exclude properties exposed to multiple wildfire events, making their setting closer to a discrete salience event than to renewed attention around a familiar, repeatedly experienced local hazard. Dugstad and Sommervoll (2026) explain that pre-landslide information was largely confined to technical investigations and expert-oriented hazard maps and was often undisclosed in practice. Gibbons *et al.* (2021) interpret the emergence of effects only after the earthquakes as an awakening of public awareness of shale-gas exploration and its risks

2 Background: The Phlegraean Fields

2.1 Bradyseism

The Phlegraean Fields[7] are a vast and active volcanic area west of Naples, characterized by a caldera—a broad depressed area formed by major eruptions in the distant past. This volcanic system is close to, but distinct from, Mount Vesuvius, which was responsible for the eruption that buried Pompeii in 79 AD. Appendix Figure OA.3, Panel (a), illustrates the area's location within Italy, while Panel (b) shows a close-up satellite view.

The Phlegraean Fields are famous for being affected by bradyseism[8], a form of ground deformation involving slow subsidence phases alternating with more rapid uplift phases, the latter generally followed by shallow, low-magnitude earthquakes. These earthquakes differ from typical tectonic earthquakes, because they are driven by underlying volcanic activity rather than the movement of tectonic plates.[9] While the associated seismic activity generally does not reach high magnitudes, it is easily perceived by the population and can lead to damage to infrastructure and buildings.

The classic historical evidence of bradyseism in the Phlegraean Fields comes from the columns of the ancient Roman marketplace, the *Macellum of Pozzuoli* (see Appendix Figure OA.3, Panel (d)), where borings left by marine *Lithophaga* bivalves document that the site was submerged below sea level before re-emerging. These observations showed that the ground had undergone repeated phases of subsidence and uplift over historical time. Since at least the early nineteenth century, the phenomenon has been extensively studied.[10]

The last volcanic eruption dates back to 1538. Prior to the ongoing crisis, the most significant bradyseismic crisis occurred during 1982–1984 and involved thousands of earthquakes, two of which reached magnitude 4.0 (M_d), causing damage and panic among the population and resulting in about 30,000 residents of *Pozzuoli*'s historic center being evacuated and temporarily relocated

[7]The name "*Campi Flegrei*" comes from the ancient Greek words meaning "burning fields".

[8]The word comes from the Greek *bradýs*, meaning "slow", and *seismós*, meaning "tremor".

[9]See Appendix Figure OA.3, Panel (c), for an example of fumarolic activity, a visible surface manifestation of volcanic unrest that is part of the local physical environment in *Pozzuoli* and the surrounding Phlegraean area.

[10]In his *Italian Journey* (1816-1817), Johann Wolfgang von Goethe described the Phlegraean Fields as "the most wonderful region in the world; under the purest sky, the most treacherous ground."

before eventually subsiding without culminating in an eruption or catastrophic disaster.

The area remains densely populated, with more than one million residents, and much of its building stock is old and seismically vulnerable (Iervolino *et al.*, 2024). While earthquakes with a magnitude above 5.0 are theoretically possible, they are considered unlikely in this area (Pino *et al.*, 2025).[11] The most serious risk remains an explosive volcanic eruption, which could produce pyroclastic flows, ash columns, and toxic gas emissions. In such a scenario, retrofitting existing housing to make it earthquake-resistant would offer little protection, as the only effective response would be evacuation. For these reasons, the Phlegraean Fields caldera is one of the most closely monitored volcanic systems in the world.

A 2006 survey (Ricci *et al.*, 2013) found that volcanic-related hazards—unlike issues such as crime, traffic, trash, and unemployment—were not mentioned as a major concern by residents. [12] The survey concluded that the most concerning aspect of the study was "*the very low salience of the volcanic hazards among the Campi Flegrei population* [...]" (Ricci *et al.*, 2013).

Lastly, there is no evidence of a sudden spike in the prominence of the issue in published discourse in the years preceding the crisis. Appendix Figures OA.5 and OA.6 report Google Books NGrams data on the relative prevalence of the terms "Bradisismo/Bradyseism" and "Campi Flegrei/Phlegraean Fields" in Italian and English-language books over the period 1900–2022, respectively, and document the long-standing presence of these hazards in scientific and general-interest publications since the early twentieth century.

2.2 The Ongoing Crisis

Throughout 2023, earthquake frequency in the Phlegraean Fields increased, culminating in two quakes of magnitude 4.2 and 4.0 (M_d) on September 27 and October 3, respectively. These events were widely felt by the population, prompting people to flee into the streets, though no damage was reported. These quakes marked the onset of the current bradyseismic crisis, the timeline

[11] Recent research indicates a gradual increase in the probability of *moderate* earthquakes over the past two decades, reflecting the progressive uplift and intensification of local seismic activity that resumed after the mid-2000s and accelerated in recent years, rather than a discrete break at the onset of the 2023 crisis (Bevilacqua *et al.*, 2024; Iervolino *et al.*, 2024).

[12] Scientists sharply disagree. For instance, prominent Italian geologist and science popularizer Mario Tozzi has stated that the entire area should be turned into a natural park like Yellowstone (Corriere del Mezzogiorno, 2025).

of which is provided in Appendix Table OA.1. The 2023 bradyseismic crisis marks the peak of a long-term gradual process of crustal uplift and intensified shallow seismicity that has been ongoing at the Phlegraean Fields since the mid-2000s (Astort *et al.*, 2024; Bevilacqua *et al.*, 2024). Appendix Figure OA.4 provides the map of the events characterizing the ongoing bradyseismic crisis. To date, the crisis has produced localized and mostly minor damage, with no fatalities or catastrophic destruction, and it has not triggered any large-scale evacuation of the Phlegraean Fields: reported evacuations and temporary relocations have remained highly localized, involving selected damaged or precautionarily cleared buildings and households, mainly in *Pozzuoli*, with the most visible measures occurring after the seismic sequences of May 2024 and March 2025.

In response, the Italian government issued *Decree-Law No. 140* on October 12, 2023, which introduced urgent measures to address the situation, including updating the emergency planning through the introduction of a new Intervention Zone. Since then, vulnerability assessments, building inspections, and emergency drills have taken place throughout the Phlegraean Fields, particularly in the newly established Intervention Zone. Meanwhile, the earthquake swarm has continued, culminating in two magnitude 4.6 events recorded on March 13 and June 30, 2025.

As shown in Figure 2, the current zoning consists of:

- **Intervention Zone**: defined in response to the crisis, it identifies the areas most subject to ground deformation within the broader Red Area of the Emergency Zone. It is concentrated primarily in *Pozzuoli* and *Bacoli*, with small portions of *Naples*, and covers 84,961 residents and 15,516 residential buildings. This zone was not delineated in response to the emergence of a previously unidentified area of heightened danger, but for vulnerability assessment and emergency planning and management purposes, on the basis of measured bradyseismic uplift[13] and in light of the significant increase in residential development and population density that occurred between the previous and current crises (Legambiente, 2025).[14] Within the Intervention Zone, an even smaller Restricted Intervention Zone—centered on *Pozzuoli*, the focal point of both the ongoing and the 1982–84 crises—has been identified.

[13]Specifically, the Intervention Zone is defined as the area that has experienced ground uplift of 10 centimeters or more since 2015—or 20 centimeters since 2006. These reference points predate the onset of the current crisis.

[14]Still, its establishment may have served as a policy-driven signal which further amplified the impact of the salience shock. We explore this possibility in Section 6.

- **Emergency Zone**: identified in 2016, this zone is divided into two distinct parts, the Red and Yellow areas, housing about 500,000 and 800,000 residents, respectively. Red area municipalities are at risk for pyroclastic flows during a major eruption and in case of alarm, preventive evacuation is the only protective measure. Municipalities in the Yellow Area, instead, are vulnerable to volcanic ash fallout, which may require temporary relocation from structurally weak buildings or areas difficult to access due to ash accumulation.

Despite this sequence of events, the official alert level for the area has remained consistently yellow, corresponding to the operational phase of "Attention", where it has stood since being raised from green in 2012. Public communications throughout 2023–2025 emphasized close monitoring of seismicity and ground deformation but did not announce any change in the alert level or in the classification of long-term hazard conditions.[15]

According to the Italian National Institute of Geophysics and Volcanology (INGV), there is currently no evidence suggesting an imminent volcanic eruption, let alone one of significant magnitude. In response to widespread panic, misinformation, and alarmism in the media, the Institute issued a bulletin in 2024 clarifying the scientific evidence on the ongoing situation.[16]

Concerning seismic risk, the Phlegraean Fields municipalities were already classified as high-risk areas, i.e., areas where strong earthquakes are theoretically possible, well before the current crisis. Under the national four-zone framework introduced in 2003 (cf. Appendix Table OA.2), they were placed in Seismic Zone 2 (high risk), and the latest official update released in May 2025 continues to classify all of them in the same zone. This indicates that, despite the gradual evolution of ground deformation since 2005, no administrative re-zoning has been warranted.

A new survey conducted between November 2023 and April 2024 (Galderisi and Limongi, 2024), which explicitly benchmarks its results against those of Ricci *et al.* (2013), finds a marked

[15]At the end of our study period, on October 30, 2025, the alert-level framework was updated to introduce additional granularity within existing alert categories, distinguishing different states of disequilibrium within the yellow and orange levels. Under this more granular framework, the Phlegraean Fields remain classified at the yellow level, corresponding to medium disequilibrium, with no transition to higher alert categories, namely orange or red. On November 4, 2025, the Civil Protection Department confirmed that the alert level remained yellow; see (in Italian) https://www.protezionecivile.gov.it/it/comunicato-stampa/campi-flegrei-confermata-allerta-gialla-rischio-vulcanico/.

[16]See the official INGV statement (in Italian): https://www.ov.ingv.it/index.php/news/28-news-cf/272-campi-flegrei-lingv-chiarisce-rischio-eruttivo-e-pericolosita.

Figure 2: Intervention and Emergency Zones for Volcanic Risk in the Phlegraean Fields

(a) Intervention Zone

(b) Emergency Zone

Notes: This figure shows the Emergency Zone defined by the Italian Civil Protection Department. In Panel (a), the map shows the Intervention Zone, which primarily includes the municipalities of *Bacoli* and *Pozzuoli*, as well as a very small area of *Napoli*. Within this area, the smaller Restricted Intervention Zone is concentrated around *Pozzuoli* and the *Solfatara* crater, in the central sector of the Phlegraean Fields most directly affected by bradyseismic ground deformation and seismic unrest. We also assess the impact of the crisis on this zone in a supplementary analysis. More information on the Intervention Zone is available at https://mappe.protezionecivile.gov.it/en/risks-maps-and-dashboards/rapid-emergency-planning-phlegraean-fields/. In Panel (b), the map displays the official designation of Red and Yellow areas, available at https://mappe.protezionecivile.gov.it/en/risks-maps-and-dashboards/national-planning-phlegraean-fields/. The Red Zone includes the following Italian municipalities within the Campania region: *Pozzuoli*, *Bacoli*, *Monte di Procida*, *Giugliano in Campania*, and *Quarto*, and some neighborhoods of *Naples* and *Marano di Napoli*. The Yellow area, instead, covers: *Villaricca*, *Calvizzano*, *Casavatore*, *Mugnano di Napoli*, *Melito di Napoli*, and most neighborhoods of *Naples* and *Marano di Napoli*.

shift in perceived priorities: more than half of respondents identify bradyseism as the main problem of the Phlegraean area, compared to about 1.7% in Ricci *et al.* (2013). This difference is largely due to the ongoing bradyseismic crisis which makes this phenomenon strongly perceived in the daily life of residents, with most respondents reporting that they look for updates every time they feel an earthquake, especially through online and local newspapers (Galderisi and Limongi, 2024).

3 Data and Descriptive Statistics

We build a municipality–residential-tier–semester panel of sale and rental prices using the Real Estate Market Observatory (*Osservatorio del Mercato Immobiliare*, OMI) of the Italian Revenue Agency. OMI reports semiannual minimum and maximum quotations for the entire national territory.[17] This administrative source systematically collects semiannual information on property price ranges for the entire national territory. We use both sale and rental quotations and measure each outcome as the arithmetic mean of the minimum and maximum price values for each observation.[18] OMI distinguishes five within-municipality residential tiers (*fasce*): central, semi-central, outskirts, suburban, and extra-urban. We use these tiers to capture within-city heterogeneity.[19] The residential category includes villas, small villas, and standard and prestigious dwellings; we exclude garages and parking spaces.

OMI is our preferred source because it applies a uniform national methodology and provides comparable semiannual measures for both sale and rental markets. More granular private datasets exist, but they offer less even coverage and weaker geographic comparability. The sample covers 2020H2–2025H2. Starting in 2020H2 avoids the months of the national lockdown, when housing-market activity briefly collapsed, while preserving the longest available pre-crisis window. The final dataset is a municipality–residential-tier–semester panel.

3.1 Treatment Definitions

Treatment follows the Civil Protection classification of the Phlegraean Fields volcanic-risk zones (Figure 2). We study three nested treated groups: municipalities in the Emergency Zone, municipalities in the Red Zone, and municipalities in the Intervention Zone.

The Emergency Zone combines the Red and Yellow areas. The Red Zone includes the municipalities of *Bacoli*, *Monte di Procida*, *Pozzuoli*, and *Quarto*, plus limited portions of *Giugliano in Campania*, *Marano di Napoli*, and *Naples*.[20] The Yellow area includes the municipalities *Calviz-*

[17] Source: https://www.agenziaentrate.gov.it/portale/web/english/real-estate-market-observatory.

[18] OMI rental data capture ordinary residential leases rather than short-term tourist rentals.

[19] OMI also reports a more granular *zone* geography, but we do not use it in the main price analysis because OMI redrew zone boundaries in 2024, making pre- and post-revision observations non-comparable.

[20] In *Giugliano in Campania*, the exposed portion corresponds to a single suburban OMI tier, which we can

zano, *Casavatore*, *Melito di Napoli*, *Mugnano di Napoli*, and *Villaricca*, plus large portions of *Marano di Napoli* and *Naples*.[21]

We define the Intervention Zone treatment using *Pozzuoli* and *Bacoli*, the municipalities explicitly targeted for structural mitigation and evacuation planning in the national emergency plan.[22] In a supplementary analysis, we study the narrower Restricted Intervention Zone by treating only the residential tiers of *Pozzuoli*.

Because OMI residential tiers do not perfectly coincide with Civil Protection boundaries, the few partial-overlap cases necessarily average over areas with heterogeneous exposure; if anything, this creates attenuation bias. Treatment starts in 2023H2, when the bradyseismic crisis began in late September 2023 (Appendix Table OA.1), and is absorbing thereafter. The panel therefore contains six pre-treatment and five post-treatment semesters. To build the control sample described below, we merge OMI with ISTAT municipality characteristics and INGV seismic-risk data.[23]

3.2 Sample Construction and Descriptive Statistics

Using all Italian municipalities as controls would compare the treated area with places that differ sharply in geography, population, and exposure to natural risk, all of which are likely to shape housing prices directly.

We therefore restrict the control sample to municipalities that are: (i) in Southern mainland regions; (ii) in seismic zones 2 or 3; (iii) within the population range of treated municipalities; and (iv) outside Campania, to limit spillovers.[24] These restrictions are based on observable treated-

identify separately. We therefore treat only that tier and exclude the remaining tiers from both treated and control groups.

[21] *Marano di Napoli* and *Naples* span neighborhoods with different exposure categories, but OMI tiers do not isolate the smaller Red-Zone portions. We therefore classify both municipalities as part of the Emergency Zone, but not the Red Zone. This choice tends to attenuate treatment intensity rather than generate spurious exposure.

[22] We exclude the small portion of *Naples* inside the Intervention Zone because it belongs to a broader OMI tier that cannot be cleanly separated from unaffected areas.

[23] We also use ISTAT monthly municipal demographic-balance data to provide ancillary descriptive evidence on formal mobility flows in the Intervention Zone.

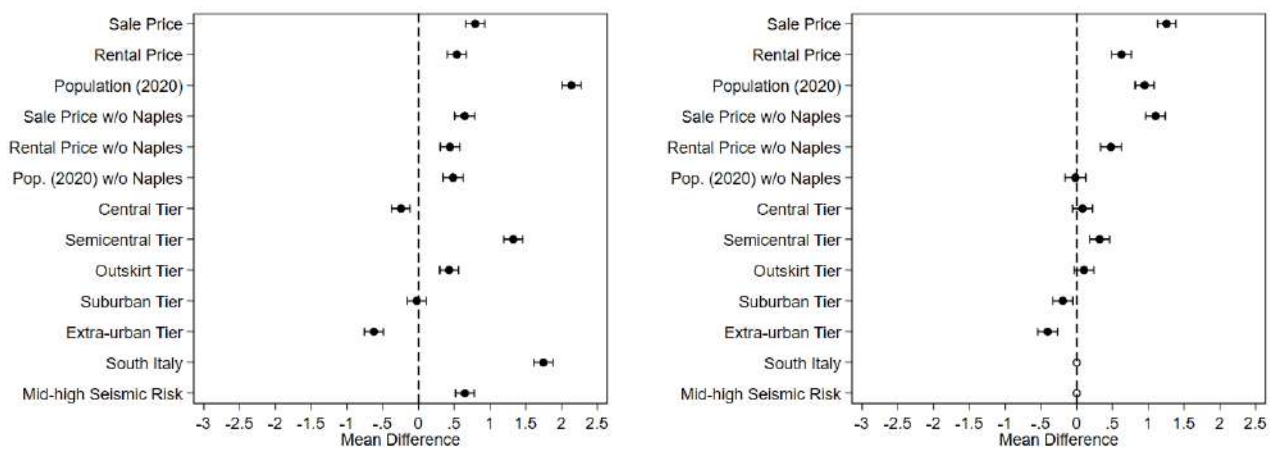
[24] All treated municipalities are in Campania and seismic zone 2. We include both zones 2 and 3 among controls to preserve a reasonable number of comparison municipalities and clusters; results are similar if controls are limited to zone 2. The population restriction avoids extrapolating to much smaller rural towns or much larger metropolitan areas.

area characteristics rather than on post-treatment outcomes.

Figure 3 shows that the restriction materially improves pre-treatment balance. In the full national sample, several standardized differences exceed 0.5 standard deviations. In the restricted sample, most shrink substantially, and they shrink further once Naples is excluded from the outcome and population comparisons. The remaining imbalance is therefore driven largely by Naples' exceptional size and market structure, which we address in the empirical specification with a Yellow Zone–specific time trend.[25]

Figure 3: Balancing of Characteristics - Treated vs Controls in the Pre-treatment Period

(a) Before (b) After



Notes: This figure plots standardized pre-treatment differences (treated minus control) before and after the control-sample restrictions. Bars denote 95% confidence intervals. Panel (a) uses all Italian municipalities. Panel (b) restricts controls to Southern mainland municipalities in seismic zones 2 or 3, within the treated population range, and outside Campania. Outcome and population variables are also shown excluding Naples. After the restrictions, *South Italy* and *Mid-high Seismic Risk* are constant by construction.

Appendix Table OA.4 reports the full summary statistics for the restricted sample. The main takeaway is simple: treated municipalities, especially those in the Intervention Zone, are substantially more expensive than controls in both sale and rental markets.

Finally, Table OA.5 shows that the attention shock linked to the Phlegraean Fields was overwhelmingly concentrated in Campania, rather than broadly diffused across Italy.

[25]Because *Naples* belongs to the Yellow Zone, the empirical strategy in Section 4 allows for a Yellow Zone–specific trend.

3.3 Description of the Complementary Data Sources

For the mechanism analysis in Section 5.1, we complement OMI with measures of physical seismic salience and media salience. Physical salience is constructed from INGV earthquake data for treated and control municipalities. At the municipality–semester level, we measure the number of events and, most importantly, Peak Ground Acceleration (PGA).[26] We focus on PGA because it captures local shaking more directly than event magnitude. Online Appendix C.1 describes the aggregation procedure and alternative PGA summaries.

We measure media salience primarily with *ANSA Regional*. Because Italian newspaper coverage is organized regionally rather than municipally, we assign articles to municipalities using LLM-assisted text classification. This is consistent with the structure of the Italian newspaper market, where local news is typically supplied by local and national outlets rather than by systematic municipal-level newspapers (Drago *et al.*, 2014). The resulting municipality–semester measures capture geographically targeted news exposure specifically related to environmental risk and housing markets.[27] Google Trends search data provide complementary evidence on public attention. Additional details on the media variables and the LLM-assisted classification are provided in Section 5.1 and Online Appendix C.2.

To study market mechanisms, we also use municipality–semester data from *Immobiliare.it*, Italy's largest real-estate portal.[28] Recent work shows that these data provide timely and geographically granular information on housing-market conditions (Guglielminetti *et al.*, 2023; Crispino and Loberto, 2025; Loberto *et al.*, 2022). These data reveal margins that are not observed in OMI: demand through *spending potential*, defined as the average budget implied by users' maximum-price and minimum-surface search filters (i.e., willingness to pay); supply through the flow of new listings entering the portal in each municipality-semester; and, for sales, an independent transaction-price series. We use these data to study demand and supply responses and to

[26] We also use INGV ShakeMap data to build the descriptive Modified Mercalli Intensity (MMI) measure in Figure 1. The construction of both MMI and PGA is described in the Online Appendix.

[27] These measures should be interpreted as geographically targeted exposure to Phlegraean Fields news, not as media strictly confined within municipal boundaries.

[28] See `https://www.immobiliare.it/`.

validate the sale-price pattern.[29]

Finally, we use survey data from the Bank of Italy's Survey on Household Income and Wealth (SHIW) as external descriptive evidence for the assumptions of the model (Section 6.1). Appendix Table OA.3 summarizes all data sources and variables used in the analysis.

4 Empirical Strategy

4.1 Event Study Design

To establish a causal relationship between the bradyseismic crisis in the Phlegraean Fields and real estate market prices, we estimate the following event-study equation:

$$Y_{m,r,t} = \alpha_0 + \sum_{j=-6}^{4} \beta_j BC_m^j + \delta_c + \delta_r + \delta_t + \varepsilon_{m,r,t} \tag{1}$$

where $Y_{m,t}$ denotes the outcome of interest (e.g., average sale or rental price of residential real estate), measured at the municipality m, residential-tier r, and time (year-semester) t. The variable BC_m^j is an event-study indicator, defined as $BC_m^j = BC_m \cdot \mathbb{1}\{t = \tilde{t} + j\}$, where BC_m is a dummy variable equal to 1 if municipality-tier m belongs to one of the treatment groups described in Section 3.1 (e.g., Intervention Zone, Red Zone, and Emergency Zone), and $\tilde{t}$ denotes the semester-year in which the bradyseismic crisis (BC) began (i.e., the second semester of 2023). Treatment adoption is simultaneous across treated units and we assume it is absorbing, meaning that once a unit is classified as treated it remains treated for all subsequent semesters in the sample, which is consistent with the institutional nature of the zone designations. The terms δ_c, δ_r, and δ_t represent municipality, residential tier, and time fixed effects, respectively.[30] Municipality and residential-tier fixed effects absorb time-invariant, or slow-moving, local amenities,

[29] OMI remains our preferred source for the core price analysis because *Immobiliare.it* differs in spatial aggregation, construction, timing, and coverage, with especially incomplete rental coverage and no rental price series. The transaction sale-price series aligns closely with OMI in levels but much less in short-run changes. Rental-side portal measures also warrant more caution because the Italian long-term rental market is smaller, more fragmented, and more likely to operate off platform.

[30] When evaluating the Emergency Zone as the treatment, we augment Equation (1) by including an interaction term between a Yellow Zone dummy and a linear time trend to account for area-specific trend dynamics, given that in the Yellow Zone there are some larger metropolitan areas characterized by a structurally different real estate market (e.g., Naples).

disamenities, and place characteristics that are typically capitalized into real estate prices, while semester-year fixed effects absorb common shocks and aggregate housing-market trends. We estimate population-weighted regressions and cluster standard errors at the municipality level, the level at which treatment is assigned (Abadie *et al.*, 2023; Roth *et al.*, 2023).[31]

The coefficients of interest, β_j for $j \geq 0$, capture the dynamic effects of the bradyseismic crisis, under the identifying assumption that in the absence of the crisis, outcome differences between treated and untreated municipalities would have remained constant over time. The plausibility of this parallel trends assumption can be assessed by inspecting the pre-crisis coefficients β_j for $j < 0$ in Equation (1). Nevertheless, to assess the robustness of our findings to alternative assumptions about counterfactual trends, we report bounds derived from the "honest" approach to difference-in-differences estimation proposed by Rambachan and Roth (2023).

Beyond parallel trends, we rely on two other standard identification assumptions in event-study research designs: absence of anticipatory behavior and the Stable Unit Treatment Value Assumption (SUTVA). The crisis began after several years of relatively low-perceptibility seismicity and minimal public attention, supporting the plausibility of the no-anticipation assumption. (cf. Appendix Figures OA.2 and OA.24). As described in Section 3.3, to address potential violations of SUTVA, we remove from the control group municipalities located in the same region (*Campania*) as the treated municipalities, thereby ruling out the risk of spillover effects on nearby unaffected areas.[32]

4.2 Synthetic Difference-in-Differences

We complement the baseline design with the synthetic difference-in-differences (SDID) approach proposed by Arkhangelsky *et al.* (2021). The SDID estimator combines features of synthetic control (Abadie *et al.*, 2010) and two-way fixed-effects difference-in-differences by constructing

[31] We weight baseline regressions by municipal population because the municipality is the relevant local housing market within which OMI residential tiers are nested. Equal weighting would target the average municipality–tier cell rather than local housing-market exposure, giving the same importance to tiers in small and large markets. Municipal population provides a stable measure of market size, while comparable residential-tier population counts are not available. In any case, the alternative SDID estimator (see below) does not rely on population weights.

[32] Section 6.4 provides evidence of spillover effects in other municipalities in the Campania region, thereby supporting the decision to exclude these municipalities from the main analysis.

unit and time weights over municipality–residential tier observations. These weights are chosen to reproduce the treated group's pre-treatment outcome path using a weighted combination of control municipality–residential tier units. Statistical inference for the SDID analysis is conducted using bootstrap standard errors with 500 replications.

The identifying assumption underlying SDID is weaker than conventional parallel trends: conditional on the weighted combination of control municipality–residential tier units that reproduces the treated group's pre-treatment outcomes, the post-treatment evolution of this synthetic control group provides a valid counterfactual for the treated units. Because the weighting relies exclusively on pre-treatment data, the approach preserves a clear separation between design and estimation. [33] Finally, SDID analysis complements the sensitivity analysis based on the honest approach proposed by Rambachan and Roth (2023). While the Rambachan–Roth procedure evaluates robustness to bounded deviations from linear pre-trends under explicit restrictions on trend changes, SDID constructs a data-driven counterfactual by reweighting control units to match the treated group's pre-treatment outcome path. Consistency of results across these two distinct approaches would further support a causal interpretation of the estimated effects.

5 Treatment Effects on Real Estate Prices

Baseline Dynamic Results. We estimate dynamic treatment effects of the bradyseismic crisis on residential sale and rental prices using the event-study specification in Equation (1). Figure 4 presents the estimates, with the left-hand graph in each panel showing effects on average *sale prices* and the right-hand graph showing effects on average *rental prices*. The three panels correspond to alternative treatment definitions: (a) Intervention Zone, (b) Red Zone, and (c) Emergency Zone.Focusing first on sale prices (left-hand graphs), Panel (a) shows a clear and economically meaningful decline in the Intervention Zone following the onset of the crisis. Pre-

[33] The SDID estimates are not meant to replicate the baseline event-study specification mechanically. By construction, SDID requires a balanced panel and is implemented on the subset of municipality–residential tier units observed in all periods. It also uses the two-way fixed-effect structure embedded in the SDID estimator, with unit and semester fixed effects, rather than the full set of fixed effects and weighting choices used in the baseline specification. We therefore interpret SDID as a complementary estimator based on a different and, in some respects, more demanding sample and specification.

treatment coefficients are close to zero and statistically insignificant, providing indirect evidence in support of the parallel trends assumption. After the shock, however, sale prices drop sharply and remain persistently below the pre-crisis level, with the magnitude of the decline increasing over subsequent semesters. Specifically, sale prices decline by approximately €26/m^2 in the first semester after the crisis, by about €35/m^2 in the second and third semesters. By the fifth post-treatment semester, it declines nearly to €60/m^2 that is approximately a 3.3% reduction relative to the average sale price observed in the last pre-crisis semester (€1,836.87/m^2).

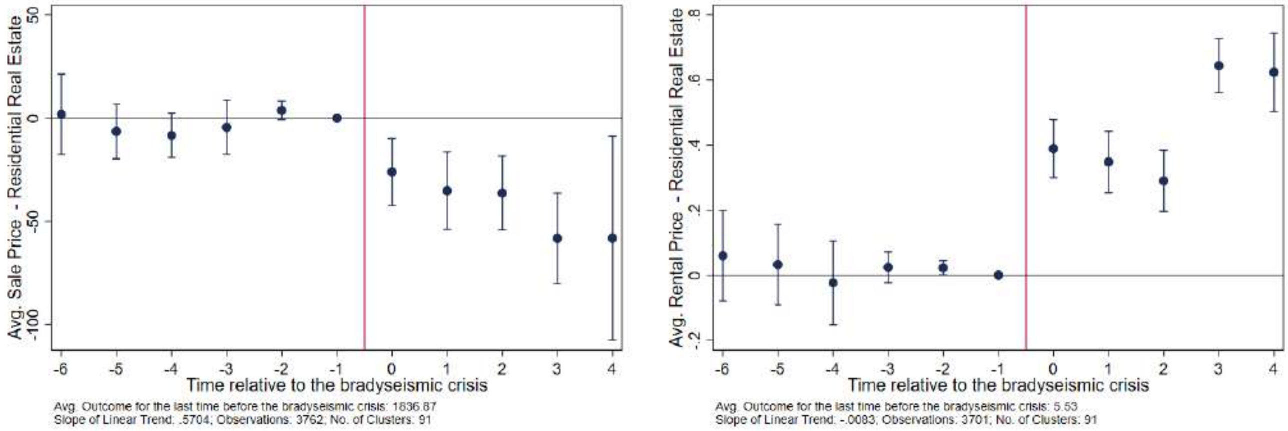
This pattern indicates a sustained contraction in property values in the areas most directly exposed to the bradyseismic crisis. In contrast, Panels (b) and (c) show no comparable decline in the Red Zone or in the broader Emergency Zone. Post-treatment coefficients in these areas are generally small and statistically imprecise, with confidence intervals including zero. Next, we turn to rental prices shown on the right-hand graphs in Figure 4. In the Intervention Zone, Panel (a), rental prices increase immediately after the crisis by approximately €0.40/m^2 in the first post-treatment semester and remain elevated thereafter, reaching about €0.64/m^2 by the fourth semester and remaining at 0.62/m^2 in the fifth. Relative to the average rental price observed in the last pre-crisis semester (€5.53/m^2), these magnitudes correspond to an increase of roughly 7% in the first semester and close to 12% at the end of the observed post-treatment window.

These effects are economically sizable and persistent over time. A similar upward dynamic is observed in the Red and Emergency Zones (Panels (b) and (c)), where rental prices also increase, indicating that the rental market response extends beyond the municipalities in the Intervention Zone.[34] A notable feature of the event-study estimates is that, after a slowdown in 2024-S2, both the negative sale-price effects in the Intervention Zone and the positive rental effects across treated zones strengthen again in 2025-S1, the second-to-last post-treatment period shown in the plots. Section 5.1 shows that this timing closely tracks the cycle of physical and media salience associated with the crisis. This temporal correspondence is important for interpretation: it suggests that the market response evolves with the intensity of the salience shock itself.

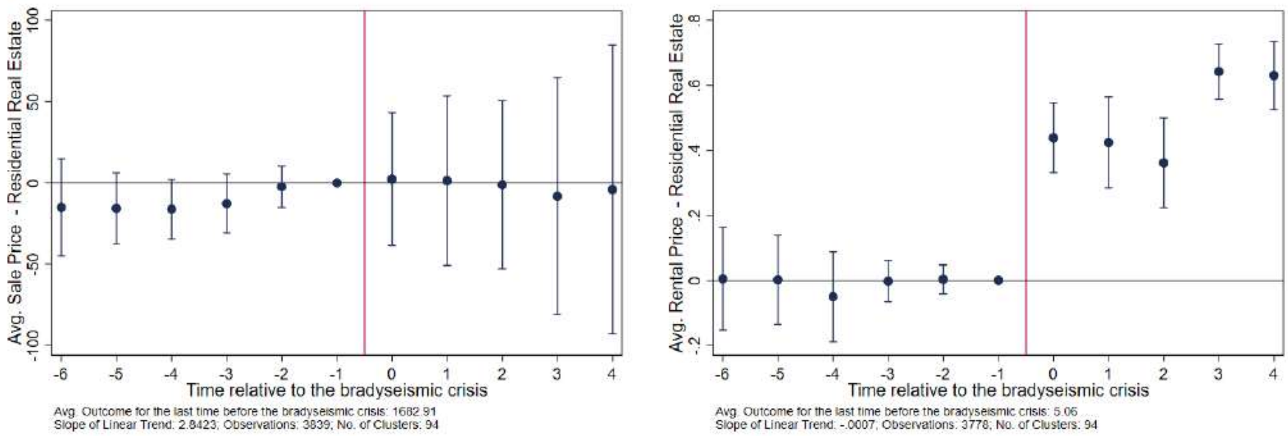
[34] Appendix Figures OA.9 and OA.10 show that the results hold when using either min or max OMI sale and rental prices, indicating that they are not driven by averaging the two price quotations. Furthermore, Appendix Figure OA.11 shows sharper effects in the Restricted Intervention Zone of *Pozzuoli*: sale prices decline more than in the broader Intervention Zone, while rental prices increase by similar magnitudes.

Figure 4: Bradyseism and Avg. Prices of Residential Real Estate

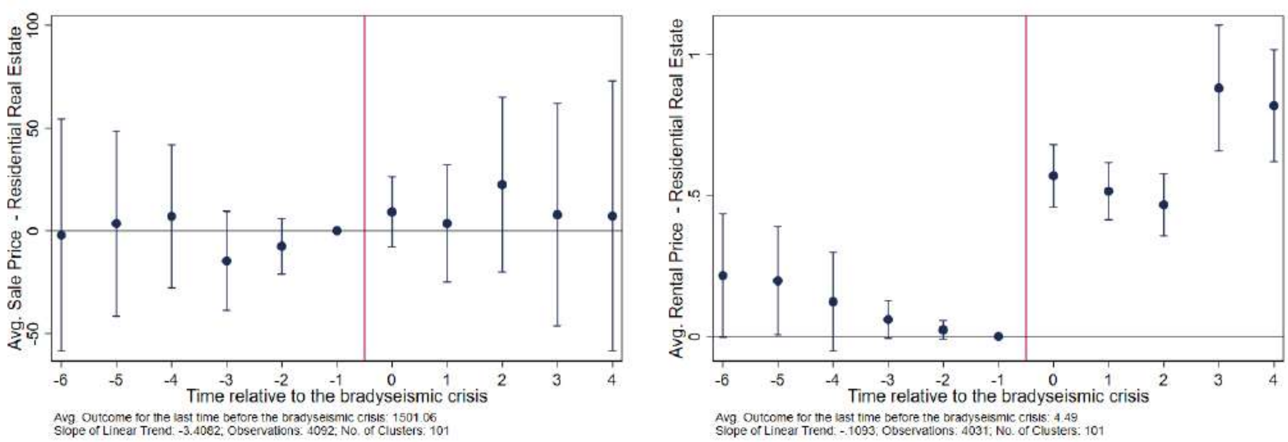
(a) Intervention Zone



(b) Red Zone



(c) Emergency Zone



Notes: This figure is organized into three panels—(a) Intervention Zone, (b) Red Zone, and (c) Emergency Zone—corresponding to different treatment definitions described in Section 3.1. Within each panel, the left-hand graph reports the event-study estimates from Equation (1) using the average residential real estate sale price as the outcome, while the right-hand graph reports the corresponding estimates for rental prices. Event-study estimates are normalized relative to semester before the bradyseismic crisis. The vertical lines indicate the time of the earthquake (treatment). In the left-hand graphs, regressions control for municipality, semester-year, and residential tier fixed effects; estimates are weighted by the population of each municipality, and 95% confidence intervals are obtained after clustering the standard errors at the municipality level. Figure OA.12 reports estimates from the "honest approach" to parallel trends proposed by Rambachan and Roth (2023).

Baseline Static Results. Table 1 reports static estimates of the average post-crisis effects. Panel A reports estimates of the static DiD equivalent of Equation (1). Panel B reports the corresponding SDID estimates. Within each treatment definition, the first column reports estimates for sale prices, while the second reports estimates for rental prices, both measured in levels.

Table 1: Static DiD and SDID - Bradyseism and Avg. Prices of Residential Real Estate

	Intervention Zone		Red Zone		Emergency Zone	
	Sale Price (1)	Rental Price (2)	Sale Price (3)	Rental Price (4)	Sale Price (5)	Rental Price (6)
Panel A: Static DiD Estimator						
Treatment	-40.514**	0.440***	8.396	0.507***	14.675	0.544***
	(16.710)	(0.059)	(38.470)	(0.076)	(18.460)	(0.058)
Observations	3,762	3,701	3,839	3,778	4,092	4,031
Avg. outcome pre-period	1829.36	5.51	1667.15	5.01	1479.26	4.43
Outcome SD pre-period	325.34	0.99	333.06	0.98	481.60	1.23
Adjusted R^2	0.742	0.725	0.744	0.725	0.745	0.747
Fixed Effects:						
Municipality FE	YES	YES	YES	YES	YES	YES
Semester-year FE	YES	YES	YES	YES	YES	YES
Residential Tier FE	YES	YES	YES	YES	YES	YES
Panel B: Static SDID Estimator						
Treatment	-33.876***	0.529***	-3.295	0.544***	2.562	0.495***
	(12.614)	(0.065)	(14.902)	(0.038)	(10.414)	(0.044)
Observations	3,762	3,685	3,839	3,762	4,092	4,015
Avg. outcome pre-period	1829.36	5.51	1667.15	5.01	1479.26	4.43
Outcome SD pre-period	325.34	0.99	333.06	0.98	481.60	1.23

Notes: This table reports static estimates of the effect of the bradyseismic crisis on residential real estate prices. Panel A reports estimates from a static version of Equation (1). Panel B reports estimates from the static synthetic difference-in-differences estimator described in Section 4.2. Columns (1)–(2) use the Intervention Zone treatment definition, columns (3)–(4) use the Red Zone treatment definition, and columns (5)–(6) use the Emergency Zone treatment definition, as described in Section 3.1. Within each treatment definition, the first column reports estimates for average residential real estate sale prices in levels, while the second column reports estimates for average residential real estate rental prices in levels. In Panel A, regressions are population-weighted and control for municipality, semester-year, and residential-tier fixed effects; standard errors are clustered at the municipality level. In Panel B, standard errors are obtained by bootstrap with 500 replications. The number of observations differs across estimators because the SDID estimator further requires a balanced panel over the relevant estimation window. Average outcome and the corresponding standard deviation are calculated for the treated in the pre-treatment period. *** p<0.01, ** p<0.05, * p<0.1.

Consistent with the dynamic evidence, the static estimates show a sharp divergence between sale and rental markets in the Intervention Zone.[35] For the broader Red Zone and Emergency

[35]In Panel A, Column (1) shows that the crisis is associated with a statistically significant decline in sale prices of €40.5 per square meter. Relative to the pre-period mean of €1,829, this corresponds to a reduction of approximately 2.2%. The SDID estimate in Panel B is similar in sign and magnitude: sale prices decline by €33.9 per square meter, or about 1.9% relative to the same pre-period mean. By contrast, rental prices in the

Zone, the sale-price results are small and statistically insignificant under both estimators. Rental prices, by contrast, rise significantly.[36] Overall, these results reinforce the main dynamic findings.

The close similarity between the DiD and SDID results is noteworthy, given that SDID constructs the counterfactual using a substantially different weighting-based estimator; this makes it less likely that the findings are driven by a particular specification of the comparison group or by common time shocks.

Overall Assessment of the Baseline Results. The combination of falling sale prices in the most exposed area and rising rents across the wider caldera is consistent with a general-equilibrium response along both tenure and space: heightened salience reduces the value of long-horizon ownership exposure in the highly perceived-risk locations, while increasing demand for rental housing as a more flexible short-run margin of adjustment.

A useful way to interpret these reduced-form patterns is in terms of two complementary margins of adjustment, which we formalize in Section 6.1. On the ownership margin, a salience shock can reduce willingness to hold long-horizon exposure in the most vulnerable locations. In the data, this is where sale prices fall: the decline is concentrated in the Intervention Zone, where exposure to the bradyseismic crisis is most direct. One interpretation is that heightened perceived risk increases the compensation households require to hold housing wealth in the most exposed locations, and that this higher risk premium is capitalized into lower transaction prices. This is especially informative because ownership markets are relatively frictional: transactions are infrequent and involve search, bargaining, financing, and listing-price frictions. A sale-price response in this market therefore suggests that the shock affected long-horizon valuations, not only short-run housing decisions.

On the rental margin, adjustment can occur more rapidly. Renting is the main tenure channel for short-run mobility, precautionary relocation, and delayed purchase decisions. The increase in

Intervention Zone increase under both estimators. The static DiD estimate is €0.44 per square meter, equal to about 8% of the pre-period mean, while the SDID estimate is €0.53 per square meter, corresponding to roughly 9.6%.

[36] In the Red Zone, the static DiD estimate is €0.51 per square meter, corresponding to about 10.1% of the pre-period mean, and the SDID estimate is €0.54 per square meter, also about 10.9%. In the Emergency Zone, the static DiD estimate is €0.54 per square meter, equal to about 12.3% of the pre-period mean, while the SDID estimate is €0.50 per square meter, or roughly 11.2%.

rents outside the Intervention Zone, especially in other parts of the caldera and nearby areas, is consistent with displaced or precautionary demand shifting toward more flexible housing arrangements. This does not require all destination areas to be objectively risk-free. In the short run, households may prioritize proximity, availability, and flexibility over a complete ranking of long-run environmental exposure. The rent response may also partly reflect speculative behavior, as anecdotal evidence reports landlords raising rents in response to increased demand from families leaving the most affected areas (il Sole24Ore (2025); Il Mattino (2025); RaiNews (2025); see also Figure OA.22).

Descriptive Evidence Supporting the Interpretation of the Baseline Results. As a direct descriptive check on the reallocation adjustment channel, Table OA.6 reports cumulative municipal registry flows for *Pozzuoli* and *Bacoli*, the two municipalities forming the core of the Intervention Zone. We compare two symmetric 27-month windows: July 2021–September 2023 for the pre-crisis period and October 2023–December 2025 for the post-crisis period. [37] Registrations from other municipalities decline by 3.3 percent, while cancellations to other municipalities increase by 11.4 percent, imply a deterioration of 0.69 percentage points of the pre-crisis population.

These registry flows provide a conservative measure of mobility responses. They capture only formal changes in registered residence and therefore miss temporary relocation, second-home use, informal accommodation, and changes in rental demand that do not involve a change in official residence. For this reason, the cumulative deterioration in net internal migration should be interpreted as a lower bound on broader mobility and housing-adjustment responses. The evidence is consistent with the decline in sale prices in the Intervention Zone and with a reduction in the attractiveness of long-horizon residential exposure in the most directly affected municipalities.

Robustness Checks and Sensitivity Analyses. To assess how strongly our findings depend on the parallel-trends assumption, we implement the sensitivity analysis proposed by Rambachan and Roth (2023). Rather than requiring treated and control outcomes to follow exactly parallel counterfactual trends, this approach constructs robust confidence sets while allowing for increas-

[37] This choice also excludes the period most directly affected by COVID-19 mobility restrictions in Italy. Results remain similar if we use the entire pre-crisis period starting in July 2020 and scale the resulting cumulative flows to account for the difference in length between the pre- and post-crisis periods.

ingly large deviations from the pre-treatment trend.[38] Appendix Figure OA.12 shows that the central findings remain stable over the range of deviations considered.

Appendix Figure OA.13 reports the baseline event-study estimates after collapsing the data to a municipality–semester panel. This exercise shows that the findings are robust to changing the spatial aggregation of the data, addressing concerns related to the Modifiable Areal Unit Problem in spatial analysis (Briant *et al.*, 2010).

As described in Section 3, OMI data do not directly capture tourism contracts or short-term tourist-rental activity. Nevertheless, to address any remaining concern that our estimates may partly reflect indirect effects of tourism on residential rental or sale prices, as an additional robustness check, Online Appendix Figure OA.14 reports estimates that control for local tourism flows.[39] Results remain unchanged.

We also check whether our results are robust to the use of an alternative source of data. Specifically, we use the *Immobiliare.it* transaction-price series, and Appendix Table OA.7 shows the same qualitative pattern as the main OMI sale-price results reported in Table 1: in the Intervention Zone, transaction prices fall by 158.3 euros per square meter in DiD and by 179.5 in SDID, while the Red- and Emergency-Zone estimates are smaller and statistically insignificant. This qualitative alignment is notable given the important differences between the two price sources, and strengthens the interpretation that the crisis depressed ownership valuations precisely where risk salience was most acute.[40]

[38] According to Rambachan and Roth (2023), the parameter $M \geq 0$ limits how much the slope of the treatment effect may vary across consecutive periods, thereby bounding the discrete analogue of its second derivative. When $M = 0$, the difference between treated and control groups is restricted to follow a linear trend, whereas higher values of M permit progressively larger departures from linearity.

[39] We rely on the Bank of Italy survey on international tourism, also used by Nocito *et al.* (2023), which interviews non-resident travelers at Italian border points and records, among other information, the date of the trip, tourists' country of origin, and municipalities visited. We aggregate tourist visits from EU28 and OECD countries to the municipality–semester level and re-estimate Equation (1) including the number of tourists as an additional control.

[40] Relative to the treated-unit pre-period mean reported in Appendix Table OA.7, the *Immobiliare.it* effects correspond to declines of about 9.0 and 10.2 percent, respectively, and are therefore substantially larger than the corresponding OMI estimates. We interpret these magnitudes cautiously, however, because the two sale-price series are much more closely aligned in levels than in changes. As discussed in Section 3.3, the correlation of semester-to-semester percentage changes is only 0.086, and the average absolute gap between the two series' changes is 10.4 percentage points, mostly reflecting the greater volatility of the *Immobiliare.it* transaction-price series. The transaction-price results are therefore most informative about the qualitative pattern of the ownership response—its sign and spatial ranking—rather than about directly comparable effect magnitudes. Transaction prices for rents are not available in *Immobiliare.it* data.

Finally, given the modest number of treated municipalities, we also complement conventional asymptotic inference with randomization inference tests, which provide a particularly informative finite-sample benchmark in settings with few treated clusters (Conley and Taber, 2011; MacKinnon and Webb, 2020; Roth *et al.*, 2023). Following the treatment-reassignment approach based on randomization inference (Belloc *et al.*, 2016; Dell and Olken, 2020; Young, 2019), we repeatedly assign treatment to otherwise untreated municipalities with comparable seismic risk, preserving the number of treated units under each zone definition, and compare the resulting placebo distributions with the observed estimates. Appendix Section B.1 presents the random inference analyses and the corresponding results. The randomization-inference p-values broadly corroborate the baseline findings: the placebo distributions are centered close to zero, the observed sale-price estimates are approximately 15 to 20 times larger in absolute value than the corresponding average placebo estimates, and the average placebo effects on rental prices are virtually zero. These results reduce concerns that our findings reflect finite-sample bias or spurious correlations and indicate that the estimated response is localized to the Phlegraean crisis rather than capturing a generalized repricing of seismic risk across Italy.

5.1 Salience: Physical Experience and Media Attention

The evidence so far shows that the bradyseismic crisis changed housing-market outcomes, but the crisis itself combined several dimensions of salience. Some households directly experienced stronger shaking and more frequent seismic activity; others may have been exposed mainly through the public narrative generated by media coverage. This distinction follows the idea that risks become behaviorally relevant both through direct experience and through mediated availability (Tversky and Kahneman, 1973, 1974; Bordalo *et al.*, 2012). It is also consistent with a broader literature showing that media reporting can affect economic and political behavior, including government accountability, disaster relief, voter turnout, political attitudes, and citizen knowledge (Besley and Burgess, 2002; Strömberg, 2004; Eisensee and Strömberg, 2007; DellaVigna and Kaplan, 2007; Enikolopov *et al.*, 2011; Snyder and Strömberg, 2010; Besley *et al.*, 2026).[41] To separate these

[41] In housing and environmental-risk settings, recent work further shows that media coverage and public announcements can make risks salient to real estate markets (Ando *et al.*, 2017; Agarwal *et al.*, 2025).

channels, we augment the static difference-in-differences specification with interactions between treatment exposure and two measures of salience: a physical salience score and a residualized media salience score.

The two scores are constructed from the seismic and newspaper data.[42] The physical salience score is the one-factor score extracted from average peak ground acceleration and the number of seismic events. The media salience score is the one-factor score extracted from the share of newspaper articles talking about environmental risk and the share of those talking about real estate, separately by reassurance, fear, and neutral tone.[43] When we use news shares, the numerator is scaled by the relevant total volume of news in the same media environment. This follows the logic in Besley *et al.* (2026): news about a specific risk should matter more when it is prominent relative to other news, while the same stories may have weaker behavioral effects when they are crowded out by unrelated coverage.

Since media coverage may mechanically respond to the same seismic activity that produces direct physical experience, we residualize the media factor by regressing it on the physical salience factor with municipality and semester fixed effects. The resulting residual media score therefore captures the component of media attention that is orthogonal to contemporaneous local physical intensity, conditional on these fixed effects. All salience measures used in the regressions are standardized after factor analysis and, when applicable, after residualization, so that interaction coefficients can be interpreted as the effect of a one-standard-deviation increase in the corresponding salience component. In Equation (2), physical salience enters contemporaneously, while residualized media salience enters with a one-semester lag. This timing is natural in our semiannual panel: physical salience captures the immediate intensity of seismic experience during

[42] Online Appendix C describes the construction of the seismic and media variables used as inputs for the salience scores. A sample article discussing fear, household relocation, and rent speculation is reported in Figure OA.22. Online Appendix D provides additional descriptive evidence on these inputs: Figure OA.21 reports before-after changes in the media and seismic measures, Figure OA.23 shows the weekly co-movement between major seismic events and media coverage, Figure OA.24 decomposes the media cycle by tone, and Table OA.9 reports static DiD estimates for the tone-specific news measures on recent environmental risk and real estate.

[43] For both scores, we first standardize the underlying inputs. With respect to the media score, we obtain similar results when using the share of articles talking about environmental risk and the the share of those on real estate, directly. We prefer the factor score based on tone-specific article shares because these sentiment dimensions may respond differently to the bradyseismic crisis, as suggested by Appendix Table OA.9. The factor score therefore provides a more informative summary of the common media salience component than a single aggregate shares.

the current housing-market semester, whereas media salience may operate through a more gradual information channel, as coverage can coincide with, follow, or re-emerge after major seismic episodes, as shown in Appendix Figure OA.23.[44]

Formally, for each treatment definition $g \in \{\text{Intervention Zone}, \text{Red Zone}, \text{Emergency Zone}\}$, we estimate:

$$Y_{m,r,t} = \alpha + \beta D^g_{m,t} + \theta_P \left(D^g_{m,t} \times P_{m,t}\right) + \theta_M \left(D^g_{m,t} \times M_{m,t-1}\right) + \pi_P P_{m,t} + \pi_M M_{m,t-1} + \delta_m + \delta_f + \delta_t + \varepsilon_{m,r,t} \quad (2)$$

where $Y_{m,r,t}$ is the sale or rental price in municipality m, residential-tier r, and semester t; $D^g_{m,t}$ is the absorbing post-crisis treatment indicator for treatment group g; $P_{m,t}$ is physical salience; and $M_{m,t-1}$ is lagged residualized media salience. The coefficients θ_P and θ_M indicate whether the treatment effect is stronger or weaker in treated observations with higher physical or media salience. The total treatment effect reported in Table 2 is the linear combination of β, θ_P, and θ_M, evaluated at the post-treatment mean salience values among treated observations in the estimation sample.[45]

Table 2 shows that physical experience decreases sale-price in the more directly exposed treatment definitions. The interaction between treatment and physical salience is negative and precisely estimated for sale prices in the Intervention Zone (-11.151) and in the Red Zone (-14.997). The coefficient remains negative in the broader Emergency Zone (-7.036), although it is less precisely estimated. Thus, conditional on the average post-crisis treatment effect, treated municipality that experienced stronger contemporaneous shaking and more frequent seismic activity tend to exhibit larger sale-price declines. This pattern is consistent with direct physical experience making long-run location risk more vivid and therefore more strongly capitalized into ownership values.

Lagged residualized media salience is a strong amplification channel for sale prices across all treatment definitions. The interaction is negative and statistically significant in the Intervention

[44] The lag structure is also in line with Besley *et al.* (2026), who relate tourism activity to lagged news coverage and violent events, allowing the information environment to shape subsequent behavior rather than contemporaneous reporting alone. In our setting, this timing is also plausible because media coverage is more likely to affect search, bargaining, and negotiation processes that are ongoing during the semester of coverage and are completed in the following semester, rather than transactions whose terms are already being finalized within the same semester.

[45] As in the baseline static specifications, regressions are population-weighted and include municipality, semester-year, and residential-tier fixed effects, with standard errors clustered at the municipality level.

Table 2: Static DiD with Salience Interactions - Bradyseism and Avg. Prices

	Intervention Zone		Red Zone		Emergency Zone	
	Sale Price (1)	Rental Price (2)	Sale Price (3)	Rental Price (4)	Sale Price (5)	Rental Price (6)
Total Treatment Effect	-56.66***	0.408***	-7.205	0.488***	15.09	0.484***
	(16.14)	(0.122)	(24.09)	(0.105)	(17.39)	(0.118)
Treatment	24.635	0.331	80.299***	0.518***	41.075***	0.267***
	(17.602)	(0.252)	(27.142)	(0.095)	(12.688)	(0.082)
Treat. × Physical Saliency	-11.151***	0.016	-14.997***	-0.000	-7.036	0.067
	(3.545)	(0.030)	(3.020)	(0.014)	(4.409)	(0.041)
Treat. × Lagged Residual Media Saliency	-8.581***	-0.004	-10.677***	-0.017	-7.701***	0.003
	(1.577)	(0.016)	(2.638)	(0.013)	(2.799)	(0.018)
Observations	3,420	3,359	3,490	3,429	3,720	3,659
Avg. outcome pre-period	1829.36	5.51	1667.15	5.01	1479.26	4.43
Outcome SD pre-period	325.34	0.99	333.06	0.98	481.60	1.23
Adjusted R^2	0.741	0.723	0.743	0.724	0.744	0.746
Municipality FE	YES	YES	YES	YES	YES	YES
Semester-year FE	YES	YES	YES	YES	YES	YES
Residential Tier FE	YES	YES	YES	YES	YES	YES
Saliency Scores FE	YES	YES	YES	YES	YES	YES

Notes: This table reports estimates from a static DiD specification (2) augmented with interactions between the treatment indicator and salience measures. Columns (1)–(2) use the Intervention Zone treatment definition, columns (3)–(4) use the Red Zone treatment definition, and columns (5)–(6) use the Emergency Zone treatment definition. Within each treatment definition, the first column reports estimates for average residential real estate sale prices in levels, while the second column reports estimates for average residential real estate rental prices in levels. *Physical Saliency* is the factor score based on physical/seismic salience measures, while *Lagged Residual Media Saliency* is the one-period lag of the residualized media salience factor score. Salience measures are standardized after factor analysis and, when applicable, after residualization. The total treatment effect is computed as a linear combination of the treatment coefficient and the two interaction coefficients, evaluated at the mean values of physical saliency and lagged residualized media saliency among treated observations in the estimation sample. Population-weighted regressions control for municipality, semester-year, residential tier fixed effects, and the salience score main effects. When the treatment is defined over the full Emergency Zone, regressions also include a Yellow Zone linear trend among the fixed effects. Average outcome and the corresponding standar deviation are calculated for the treated in the pre-treatment period. Standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.1.

Zone (−8.581), the Red Zone (−10.677), and the Emergency Zone (−7.701). This pattern indicates that newspaper attention in the previous semester is associated with stronger subsequent price reductions not only in the most narrowly exposed area, but throughout the full set of treatment definitions. The evidence is therefore consistent with a broad information-salience channel: once direct physical salience is netted out, the residual media environment still predicts stronger capitalization of perceived risk into ownership values. In this respect, our setting is close to the media-salience channel studied by Ando *et al.* (2017) for nuclear risk, by Agarwal *et al.* (2025) for sea-level-rise exposure, and by Besley *et al.* (2026) for the economic response to news about violence.[46] It differs, however, because the media shock occurs in a setting where the underlying

[46] Our analysis is related to the idea of a media multiplier (Besley *et al.*, 2026), whereby media coverage amplifies

hazard was already long known and no official alert-level reclassification occurred. Descriptives in the Online Appendix D support this interpretation: media attention rises sharply after the bradyseismic escalation, co-moves with the main seismic episodes, and is driven especially by articles on environmental risk and on real estate, with a marked increase in fear-related coverage (Appendix Figures OA.21–OA.24 and Table OA.9).

For rental prices, the total treatment effects remain positive and precisely estimated in all three treatment definitions: rents increase by about €0.41/m^2 in the Intervention Zone, €0.49/m^2 in the Red Zone, and €0.48/m^2 in the Emergency Zone. At the same time, the salience interactions are more muted than for sale prices. Physical salience does not significantly increase rents in the Intervention or Red Zones and is positive but imprecise in the Emergency Zone. Lagged residualized media salience is also small and statistically insignificant for rental prices. This suggests that the rental response does not operate primarily through a direct salience channel. Rents rise in the baseline estimates, but not disproportionately in the municipality-tier cells where local shaking or media attention is strongest. This pattern is more consistent with an indirect equilibrium effect: heightened salience depresses ownership demand, and the resulting tenure reallocation raises demand for rental housing more broadly across the treated area.

Although the hazard was already known ex-ante, the establishment of the Intervention Zone under Decree-Law No. 140/2023 could have generated an additional source of institutional salience. In particular, residents may have interpreted the policy response as a signal that risk had increased, even though it did not coincide with an upward revision of the official alert level. To assess whether this policy-salience channel drives our results, we augment Equation (2) with an additional interaction between treatment status and the one-semester lag of the share of newspaper coverage mentioning both Decree-Law No. 140/2023 and the Intervention Zone. As in the media-salience decomposition above, this decree-news measure is residualized with respect to physical salience and then standardized.[47]

the behavioral effects of underlying shocks. Unlike Besley et al., however, we do not estimate a structural media multiplier. Rather, we examine whether media salience amplifies the market response to environmental risk.

[47]The share of decree-related news is always zero in the pre-treatment period; therefore, we residualize the measure with respect to physical salience only in the post-treatment period to avoid mechanically altering the pre-treatment variation and introducing spurious residual values before the decree was introduced.

Appendix Table OA.10 reports the results. The decree-news interaction is small and statistically insignificant for sale prices in the Intervention Zone (-0.681), indicating that attention to the decree does not further depress ownership values in the area directly targeted by the policy. A natural interpretation is that households considering a long-horizon purchase in the Intervention Zone were already discouraged by physical experience and general media salience; additional coverage of the decree did not add much further information for the sale market. By contrast, the decree-news interaction is negative and statistically significant for rents in the Intervention Zone (-0.034). This is consistent with the idea that, when media coverage focuses heavily on the decree and the newly established Intervention Zone, even households that might otherwise have remained as renters may decide to leave or avoid renting in the most explicitly named area.

The decree-news interaction is different in the broader Emergency Zone. For sale prices, it is positive and statistically significant (2.743), while the corresponding rental-price interaction is positive but not statistically significant. One possible rationale is that, in the broad Emergency Zone, decree-related media coverage may identify a narrower set of places as the most institutionally salient and directly targeted by the policy. For municipalities or residential tiers inside the broader emergency area but not explicitly associated with the decree, this information may be relatively reassuring, encouraging households to reallocate toward nearby locations that remain close to the caldera but are not named as the core intervention area.[48]

Overall, however, these decree-news interactions are economically small relative to the main treatment effects, suggesting that decree-specific attention plays at most a marginal role in explaining the housing-market response. Consistent with this interpretation, Google Trends data for Campania show no measurable search interest for the policy-specific queries "*Decreto Legge 140/2023*" (Decree-Law 140/2023) and "*Zona di Intervento*" (Intervention Zone) over the 2023–2025 period.[49]

Taken together, thes analyses supports two conclusions. First, the ownership-market response

[48] The Red Zone estimates are less informative on this margin: decree-news interactions are not statistically significant for either sale prices or rental prices.

[49] Google Trends queries are available for "*Decreto Legge 140/2023*" at `https://trends.google.it/explore?q=Decreto%20Legge%20140%2F2023&date=2023-01-01%202025-12-31&geo=IT-72` and for "*Zona di Intervento*" at `https://trends.google.it/explore?q=Zona%2520di%2520intervento&date=2023-01-01%202025-12-31&geo=IT-72`.

is shaped by both direct physical experience and media attention. Stronger local seismic perceptibility robustly decreases sale-price declines in the most exposed treatment definitions, while lagged residual media salience is negative and precisely estimated for sale prices across all treatment definitions, and amplifies the physical experience. The media effect is therefore not confined to the narrow Intervention Zone; it is a broader channel through which attention to the crisis is capitalized into ownership values.

Second, the rental-market response appears to operate through a different margin. Rents rise substantially in the main DiD estimates, but the salience interactions in Table 2 do not show that rents rise mechanically where physical or media salience is highest. Instead, the decree-news results in Table OA.10 suggest that institutionally specific media attention may attenuate rental demand in the most explicitly targeted area. This pattern is consistent with news narratives emphasizing relocation pressure, rent speculation, and housing-market stress, which may discourage households from renting in the most exposed markets even as broader demand for flexible housing increases elsewhere. We provide some anecdotal evidence in Appendix Figure OA.22.

6 Interpretation and Mechanisms

6.1 A Dynamic Tenure and Spatial Substitution Mechanism

We develop a simple framework to rationalize the central empirical pattern in the paper: in the more exposed Intervention Zone, sale prices decline while rental prices increase. The model also clarifies why the same salience shock may generate heterogeneous effects across local residential tiers and spillovers to nearby municipalities. The key point is that salience affects housing markets through two complementary margins. First, it changes tenure choice by reducing the attractiveness of ownership relative to renting. Second, it induces spatial substitution across nearby locations and across residential tiers within the Intervention Zone.

The framework builds on the hedonic interpretation of housing markets. In hedonic and spatial equilibrium models, property values and rents are equilibrium objects that summarize households' willingness to pay for location attributes, including perceived exposure to environmental risk (Rosen, 1974; Roback, 1982; Chay and Greenstone, 2005). In our setting, the underlying hazard was already known and monitored; the relevant question is therefore not whether prices reveal the existence of risk, but whether a salience shock changes the perceived cost and behavioral relevance of that risk.[50]

The mechanism is intentionally parsimonious. A rise in environmental risk salience increases the perceived cost of long-horizon exposure embedded in ownership, reducing willingness to buy in the most exposed locations. At the same time, salience affects households at the moment in which they would normally transition from renting to owning: some delay ownership but remain locally tied by work and family constraints, while others adjust spatially toward nearby areas perceived as safer. Because rental supply is inelastic in the short run, these tenure and spatial substitutions can raise rents even as ownership values fall in the most exposed market.

Time is discrete. There are two local housing submarkets. Location E is the exposed area, corresponding to the Intervention Zone or to the most directly affected residential segments within it. Location S is a nearby receiving area perceived as safer, which may be another residential tier within the same municipality, another zone within the caldera, or a nearby municipality outside the treated area. Objective hazard is $h_E > h_S \geq 0$.[51]

Attention to a known but previously low-salience risk can change market allocation even when objective hazard does not discretely change. In a durable-asset market, salience may lower the value of ownership exposure while raising the value of flexible housing, creating an ownership–rental divergence and spatial reallocation. Households do not react only to objective hazard. They react to perceived hazard,

$$\pi_{jt} = s_t h_j, \qquad j \in \{E, S\}, \tag{3}$$

where s_t denotes the salience of environmental risk. Before the bradyseismic crisis, $s_t = s_0$. The crisis raises salience to $s_1 > s_0$ through perceptible earthquakes, media attention, emergency

[50] The model is related to standard theories of housing tenure choice and housing-market dynamics over the life cycle (Henderson and Ioannides, 1983; Ortalo-Magne and Rady, 2006), and to the idea that ownership embeds long-run exposure to local housing-market risk (Sinai and Souleles, 2005). The salience shock follows the behavioral insight that recent, vivid, or repeatedly communicated risks receive disproportionate weight in beliefs and choices (Tversky and Kahneman, 1973, 1974; Bordalo *et al.*, 2012).

[51] Thus, E and S should be interpreted flexibly. They may denote different municipalities, but they may also denote different residential tiers within the same Intervention-Zone municipality.

planning, drills, and inspections, without requiring an abrupt change in objective hazard or an upward revision of the official alert level.

In each period, a mass n of young workers enters the local housing market. Young workers rent because they have low savings, uncertain job matches, and short expected residence horizons. After one period, they become mature workers. Mature workers are more likely to consider buying a house, but they may also continue renting if uncertainty rises.

Households differ in local attachment a. Moving from E to S entails a cost $c(a)$, with $c'(a) > 0$. This captures family ties, commuting costs, school choices, local employment, liquidity constraints, and search frictions. Moving farther away would entail an even larger cost, so short-run adjustment is primarily local or nearby. This assumption links the model to both within-zone heterogeneity and spillovers to nearby areas.

Conditional on location j, a mature household chooses whether to buy or rent. Buying is a long-horizon commitment. Let $T > 1$ denote the effective exposure horizon under ownership. The indirect value of buying in location j is:

$$V_{jt}^{B} = T u_j - P_{jt} - T\theta_B \pi_{jt}, \tag{4}$$

where P_{jt} is the sale price, u_j is the per-period housing-service value, and $\theta_B > 0$ is the perceived utility cost of environmental risk exposure under ownership. Renting is more flexible:

$$V_{jt}^{R} = u_j - R_{jt} - \theta_R \pi_{jt} + F, \tag{5}$$

where R_{jt} is rent and $F \geq 0$ is the option value of flexibility. Since renters can adjust more rapidly, $\theta_R < T\theta_B$.

The household buys in location j if $V_{jt}^{B} \geq V_{jt}^{R}$, or

$$P_{jt} - R_{jt} \leq (T-1)u_j - F - (T\theta_B - \theta_R)\pi_{jt}. \tag{6}$$

Equation (6) is the tenure-substitution channel. A rise in salience reduces willingness to buy, especially in locations with high objective hazard. Let $B_j(P_{jt}, R_{jt}, \pi_{jt})$ denote purchase demand in location j. Then

$$\frac{\partial B_j}{\partial P_{jt}} < 0, \qquad \frac{\partial B_j}{\partial R_{jt}} > 0, \qquad \frac{\partial B_j}{\partial \pi_{jt}} < 0. \tag{7}$$

The same shock also changes the spatial allocation of demand. If a household can remain locally attached while moving from a more exposed or less desirable segment E to a nearby segment S, the perceived-risk gain from moving is:

$$\Delta\pi_t = \pi_{Et} - \pi_{St} = s_t(h_E - h_S). \tag{8}$$

The household moves when this perceived-risk gain, net of moving costs and amenity differences, is large enough. Hence, the salience shock can generate spatial substitution from more exposed residential tiers toward nearby tiers that are perceived as relatively safer.[52]

Appendix E.1 provides the full derivation of the spatial-adjustment and market-clearing conditions. The model delivers four empirical predictions.

First, sale prices fall in the most exposed ownership market. The salience shock lowers willingness to buy because ownership capitalizes long-run perceived disaster exposure. This effect is strongest in the Intervention Zone and in the most exposed segments within it.

Second, rents may rise even where sale prices fall. Households that would have transitioned from renting to owning delay the purchase decision. If they are locally attached, they remain in the rental market. Together with the continued entry of young workers, this congests rental demand and raises rents when short-run rental supply is inelastic.

Third, the shock generates spatial substitution. Some households leave the most exposed residential segments and move toward nearby locations perceived as safer. These destinations may be other tiers within the same municipality, other areas in the caldera, or nearby municipalities outside the treated zone. The model therefore predicts spillovers in receiving markets.

Fourth, heterogeneity depends on the interaction between tenure substitution and spatial substitution. Areas in which the ownership-risk discount is strong and local rental demand remains constrained can display an ownership–rental divergence, with sale prices falling and rents rising.

[52]This mechanism could be further amplified if individuals perceive the crisis as also changing amenity values across residential tiers, for example through a decline in local services in highly exposed tiers due to outflows.

Areas that receive inflows may experience increases in both sale and rental prices, while areas that lose demand may experience declines in both.[53]

The central implication is that the opposite movement of sale and rental prices is not anomalous once households can adjust along both tenure and spatial margins. In normal periods, common local fundamentals tend to move rents and sale prices in the same direction. After a salience shock, however, ownership becomes less attractive in exposed locations because it is a long-horizon risky asset, while renting becomes a flexibility-preserving response for households that remain locally constrained. Spatial reallocation then determines where the resulting demand pressure is capitalized. This joint mechanism predicts a spatial gradient: some residential tiers may display the ownership–rental divergence emphasized by the baseline results, while others may move along a common demand-reallocation gradient with both prices rising or both prices falling.

Consistent with these assumptions, Online Appendix E.2 and Appendix Table OA.11 report SHIW evidence showing that, in Campania, tenure choices follow a life-cycle pattern, home purchases are predominantly local, and earthquake insurance coverage is very limited, supporting the model's emphasis on delayed ownership and local attachment.[54]

6.2 Demand and Supply Responses

The demand-and-supply evidence from *Immobiliare.it* supports the mechanisms described in Section 6.1. Table 3 shows a sharp contraction in buyer-side demand in the most exposed ownership market. In the Intervention Zone, sale-market spending potential falls by 308.8 euros per square meter in the baseline DiD, and by 423.3 in SDID, corresponding to declines of about 8 and 11 percent, respectively, relative to the treated-unit pre-period mean reported in the table. The effect attenuates as the treatment area widens, but the spatial gradient remains negative: in the Red

[53] Thus, the model does not require every residential tier to display opposite sale and rental signs. Instead, the ownership–rental divergence should appear most clearly in the local segments where the tenure margin dominates the spatial outflow margin.

[54] Current homeowners are older than renters on average (59.56 versus 51.63), and the same ordering appears at the tenure-entry margin: the average age at home purchase is 33.52, compared with 32.31 for entry into the current rented dwelling. Home purchases are also highly local: 93.78% of Campania homebuyers purchase in their birth region, compared with 77.34% nationally. Finally, only 2.41% of Campania households report earthquake insurance on their current residence in 2022, compared with 9.11% nationally. More details are available in the Online Appendix E.2.

Zone, the corresponding declines are about 4 percent in DiD and 8 percent in SDID, while in the Emergency Zone they are about 1 percent in DiD and 6 percent in SDID. This pattern is closely aligned with the model's core mechanism: risk salience depresses ownership demand most where exposure is highest. It also complements the main sale-price results because search-side willingness to pay is a forward-looking demand measure rather than an ex post price outcome.

Rental spending potential moves in the opposite direction in the baseline DiD estimates, rising by 1.344 in the Intervention Zone, 0.712 in the Red Zone, and 0.643 in the Emergency Zone, corresponding to increases of about 10.8, 6.5, and 6.3 percent, respectively, relative to the treated-unit pre-period means reported in the table.

This pattern is consistent with the tenure-reallocation margin: as ownership becomes less attractive in the most exposed locations, some households shift their search toward rental housing. The SDID rental-demand estimates remain positive but are smaller and statistically imprecise. We interpret these estimates cautiously because the rental side of the *Immobiliare.it* panel has more uneven coverage: even in DiD specifications, rental outcomes contain roughly half as many observations as the corresponding sale-market outcomes and are much smaller than the baseline OMI price panel. The SDID complete-panel requirement further reduces usable support, so the loss of statistical precision is not surprising.[55] In addition, the *Immobiliare.it* rental variables are search- and listing-based measures rather than realized rental contract prices. Unlike OMI rental prices, which are intended to capture ordinary residential rental-market conditions based on registered residential leases, these online rental measures may also reflect temporary or short-term rental activity.

By contrast, there is limited evidence of a broad short-run supply response in newly posted listings. The coefficients on listings entering are generally small and statistically insignificant, consistent with the model's logic: the bradyseismic crisis appears to weaken buyer-side demand in the most exposed ownership market and redirect search toward rental housing, while providing little evidence of a contemporaneous contraction in newly posted listings.

[55] For example, in the Intervention Zone, rental spending-potential observations fall from 484 in DiD to 297 in SDID, compared with 945 sale spending-potential observations in DiD. Similar reductions occur in the Red and Emergency Zones and for new rental listings.

Table 3: Demand and Supply Responses

	Sales Market		Rental Market	
	Demand	Supply	Demand	Supply
Panel A: Intervention Zone				
Treatment, DiD	-308.781^{***}	14.391	1.344^{***}	-4.969
	(69.910)	(19.631)	(0.247)	(4.383)
Treatment, SDID	-423.254^{***}	-1.937	0.564	0.642
	(117.025)	(13.385)	(0.421)	(3.695)
Observations, DiD	945	998	484	476
Observations, SDID	814	979	297	275
Avg. outcome pre-period	3,766.19	164.50	12.45	45.17
Outcome SD pre-period	415.82	125.43	1.11	36.21
Panel B: Red Zone				
Treatment, DiD	-119.425	-41.345	0.712^{*}	-6.611
	(88.513)	(34.297)	(0.368)	(3.961)
Treatment, SDID	-265.196^{*}	-23.265	0.501	-4.304
	(141.180)	(19.760)	(0.382)	(5.038)
Observations, DiD	978	1,031	516	507
Observations, SDID	847	1,012	319	297
Avg. outcome pre-period	3,199.56	227.47	10.98	49.11
Outcome SD pre-period	923.15	241.82	2.44	45.12
Panel C: Emergency Zone				
Treatment, DiD	-33.993	-24.833	0.643^{**}	64.033
	(64.745)	(23.748)	(0.257)	(43.998)
Treatment, SDID	-149.818^{**}	-41.300^{*}	0.089	-22.657
	(71.807)	(24.530)	(0.344)	(19.637)
Observations, DiD	1,055	1,108	591	581
Observations, SDID	924	1,089	385	352
Avg. outcome pre-period	2,708.82	437.43	10.20	98.46
Outcome SD pre-period	874.27	947.94	2.57	246.54

Notes: This table reports municipality-semester estimates of the effect of the bradyseismic crisis on search-side demand and listing supply using data from *Immobiliare.it*. Panels A, B, and C use the Intervention Zone, Red Zone, and Emergency Zone treatment definitions, respectively. DiD specifications include municipality and semester fixed effects; standard errors, clustered at the municipality level, are reported in parentheses. SDID specifications use unit and time fixed effects and report bootstrap standard errors based on 500 replications. Pre-period means and standard deviations are calculated on the DiD estimation sample of treated units only. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

6.3 Heterogeneous Effects Within the Intervention Zone

In light of our main findings—showing a decline in average sale prices in the Intervention Zone municipalities and a generalized increase in rental prices across all zones (Intervention, Red, and Emergency)—it is plausible that part of this reallocation is occurring *between* treated zones, with residents or prospective buyers in the Intervention Zone temporarily relocating outside the most affected areas and seeking housing in nearby zones belonging to the outside ring of the Red and Emergency zones. However, some of this reallocation may also be occurring *within* the Intervention Zone, with residents of the Intervention Zone moving away from the most exposed areas and neighborhoods toward locations perceived as safer.

We therefore use within-zone heterogeneity as a descriptive assessment of whether the cross-sectional pattern of responses is consistent with these interpretation and with some implications of the model described in Section 6.1.

The left-graph of Figure 5 provides pre-crisis price levels by tier: central and semi-central locations are the most expensive both for sales and rentals, while outskirt and suburban tiers are cheaper. These level differences plausibly reflect both (i) an amenity/accessibility component (living closer to the center is valued) and (ii) a risk component (areas perceived as less risky capitalizing into higher prices).

The right-graph of Figure 5, instead, plots the estimated post-crisis effects on average rental prices (y-axis) against those on average sale prices (x-axis) for each different residential tier of each municipality observed in the Intervention Zone (i.e., central, semi-central, outskirts, and suburban). Post-crisis (tier-specific) coefficients depicted in each scatter plot are obtained by running an augmented version of Equation (1) that reads as follows:

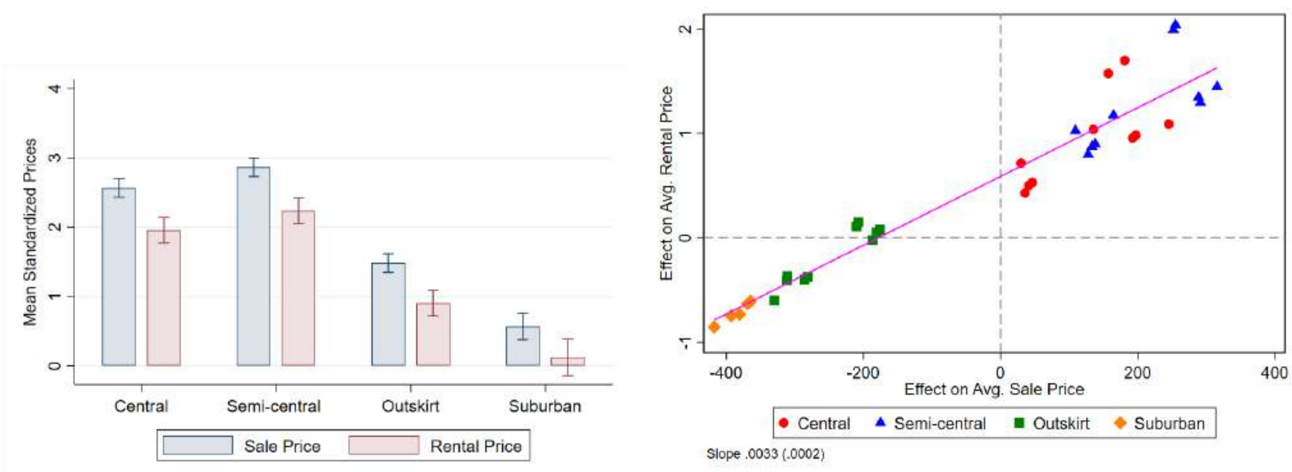
$$Y_{m,r,t} = \alpha_0 + \sum_{j=-6}^{4} \beta_j BC_m^j + \sum_{j=-6}^{4} \theta_j \left(BC_m^j \times RT\right) + \delta_c + \delta_r + \delta_t + \gamma_{m,r,t} \tag{9}$$

where RT is an indicator equal to 1 when considering a given residential tier. The scatter plots report the linear combination given by $\phi_j \equiv \beta_j + \theta_j$ for $j \geq 0$ for the aforementioned municipality tiers.[56]

[56] We estimate Equation (9) separately for each municipality in the Intervention Zone to capture the full range of potential heterogeneous effects.

Figure 5 reveals several distinct combinations of post-crisis price responses within the Intervention Zone. Some municipality–tier cells experience increases in both sale and rental prices, with the largest joint increases concentrated in semi-central tiers. Other cells experience declines in both outcomes; these losses are most pronounced in suburban *Pozzuoli*, in the areas closest to the *Solfatara* crater. Between these two groups, some cells combine lower sale prices with a small rental increase, while others exhibit a strong increase in rents accompanied by only a marginal increase in sale prices.

Figure 5: Heterogeneity Analyses Across Residential Tiers - Intervention Zone



Notes: The left panel (bar plot) reports pre-crisis mean standardized prices at the municipality-tier level (sale and rental) by residential tier for treated municipalities of the Intervention Zone. Standardized prices are constructed by z-scoring the outcome in the pre-crisis period and then regressing the standardized outcome on tier indicators without a constant; hence, each bar equals the tier-specific sample mean of the standardized outcome in the pre-crisis period. Error bars report 95% confidence intervals. The right panel (scatter plot) reports the post-crises coefficients on the average rental price of residential real estate in (y-axis) and the effect of the bradyseismic crisis on the average sale price of residential real estate in (x-axis) for a given residential tier observed in each municipality belonging to the Intervention Zone. The post-crisis, tier-specific, coefficients depicted in each scatter plot are obtained by running (9) separately for each municipality in the Intervention Zone treatment sample. We estimate this equation for each of the following residential tiers: central, semi-central, outskirt, suburban. The scatter plots report the linear combination of the estimated coefficient of Equation (9) that is given by $\phi_j \equiv \beta_j + \theta_j$ for $j \geq 0$ for the aforementioned residential tiers. The solid line reports the associated linear fit (including a constant); the corresponding slope and robust standard error are shown below the plot.

This richer pattern helps connect the within-zone evidence to the two margins highlighted by the model. A decline in sale prices alongside stable or slightly higher rents is consistent with tenure substitution from ownership toward renting among households that remain locally attached. The common movement of sale and rental prices, by contrast, is more naturally associated with spatial substitution: demand shifts away from locations perceived as more exposed and toward locations perceived as relatively safer or otherwise more desirable. Such perceptions need not reproduce official risk boundaries. Proximity to the *Solfatara*—a highly visible source of recurrent fumarolic activity—may make the hazard especially salient even without a discrete change in objective risk. The particularly large joint decline in suburban *Pozzuoli* is therefore consistent with localized outflows from the area most visibly associated with the crisis, whereas the joint appreciation of several central and semi-central cells is consistent with receiving-market pressure.

The semi-central response also points to segmentation within the local sale market. Spatial substitution across different tiers is most plausible when origin and destination properties belong to different OMI classifications but occupy nearby portions of the pre-crisis price distribution. The additional analysis in Appendix F shows precisely this overlap: higher-priced properties in outskirt and suburban tiers are comparable in price to lower- and middle-priced properties in central and semi-central tiers. The stronger semi-central appreciation can therefore reflect reallocation across tiers without requiring households to move to a substantially different segment of the housing market.

6.4 Spillover Effects

We examine whether the same spatial margin extends beyond the Phlegraean Fields.[57]

For this reason, we define six spillover groups using two institutional risk classifications: the official Italian seismic-risk zones and the Civil Protection Department's Red Zone for Mount Vesuvius.[58] As illustrated in Appendix Figure OA.8, the groups distinguish nearby high-risk municipalities in the Naples province, the Vesuvius Red Zone, other high- and medium-risk municipalities in the Naples province, and medium- and very-high-risk municipalities elsewhere in Campania. The treated Phlegraean Fields municipalities are excluded throughout. For each group, we estimate a static difference-in-differences specification analogous to Equation (1) and the corresponding

[57]This exercise also addresses the potential violation of SUTVA discussed in Section 4 and provides an empirical rationale for excluding Campania municipalities from the baseline control group.

[58]See Table OA.2 for the seismic-risk labels and Appendix Figure OA.7 for their distribution in Campania. The Vesuvius Red Zone was formally approved by Presidential Decree on 14 February 2014 and its operational guidelines published on 31 March 2015. It encompasses areas exposed to pyroclastic flows (Red Zone 1) and areas at high risk of roof collapse from pyroclastic deposits (Red Zone 2). For a full description, see https://www.protezionecivile.gov.it/it/approfondimento/aggiornamento-del-piano-nazionale-di-protezione-civile-il-vesuvio/. Of the 25 municipalities officially listed in the Red Zone, we exclude Naples, Nola, and Pomigliano d'Arco from the spillover treatment group, as only small fractions of their administrative territory fall within the designated boundary. All these municipalities fall within the Zone 2 (high seismic risk) classification.

SDID model, using the refined Southern Italian control sample described in Section 3.3. Table 4 reports the results.

Table 4: Static DiD and SDID - Spillover Effects

	NA Prov. Close High Risk (1)	Vesuvius Red Risk Zone (2)	NA Prov. Other High Risk (3)	NA Prov. Medium Risk (4)	Other Prov. Medium Risk (5)	Other Prov. V. High Risk (6)
Panel A: Avg. Sale Price						
Spillover Treatment	53.183***	40.216***	33.558***	78.941***	45.137***	-49.336***
	(9.559)	(10.693)	(11.517)	(20.001)	(7.895)	(6.934)
Spillover Treatment, SDID	4.639	7.670	5.706	73.975**	43.134***	-10.113***
	(6.924)	(6.058)	(5.463)	(29.450)	(5.162)	(3.664)
Observations	4,444	4,378	4,466	4,147	5,005	7,040
Avg. outcome pre-period	1044.94	1041.77	1063.52	1167.75	1116.91	848.63
Outcome SD pre-period	337.61	345.45	425.74	769.42	667.77	321.49
DiD Adjusted R^2	0.747	0.755	0.760	0.835	0.745	0.739
Panel B: Avg. Rental Price						
Spillover Treatment	0.461***	0.399***	0.488***	0.999***	0.037	-0.201***
	(0.052)	(0.075)	(0.072)	(0.188)	(0.043)	(0.051)
Spillover Treatment, SDID	0.394***	0.354***	0.497***	1.198***	0.062***	-0.047***
	(0.023)	(0.028)	(0.048)	(0.159)	(0.016)	(0.017)
Observations	4,367	4,301	4,389	4,070	4,928	6,963
Avg. outcome pre-period	3.73	3.73	3.70	3.97	3.66	3.30
Outcome SD pre-period	1.08	1.11	1.15	1.62	1.40	1.20
DiD Adjusted R^2	0.732	0.736	0.732	0.768	0.717	0.725
DiD model fixed effects:						
Municipality FE	YES	YES	YES	YES	YES	YES
Year-month FE	YES	YES	YES	YES	YES	YES
Residential Tier FE	YES	YES	YES	YES	YES	YES

Notes: This table reports estimates from static spillover specifications using both static difference-in-differences regressions and static synthetic difference-in-differences. The treatment indicator is replaced by each of the six spillover treatment definitions described in Section 6.4 and illustrated in Figure OA.8. The table is organized into two panels: Panel A reports results for the average residential real estate sale price and Panel B for the average rental price. Each column corresponds to a distinct spillover treatment group: (1) high-risk municipalities in the Naples province close to the Phlegraean Fields; (2) Vesuvius Red Zone municipalities; (3) other high-risk municipalities in the Naples province; (4) medium-risk municipalities in the Naples province; (5) medium-risk municipalities in other Campania provinces; (6) very-high-seismic-risk municipalities in other Campania provinces. In all specifications, the Phlegraean Fields treated municipalities are excluded from the analysis. All estimates are computed on the common support used by the static SDID estimator, requiring a balanced munfascia panel. DiD regressions are population-weighted and control for municipality, semester-year, and residential tier fixed effects, with standard errors clustered at the municipality level. SDID estimates report bootstrap standard errors based on 500 replications. *** p<0.01, ** p<0.05, * p<0.1

The comparison between estimators is informative. Rental spillovers are positive under both DiD and SDID across nearby high- and medium-risk municipalities, including the Vesuvius Red

Zone, and in medium-risk municipalities elsewhere in Campania. Sale-price spillovers are more selective: under SDID, they remain positive only in medium-risk municipalities in and outside the Naples province. Thus, the broad rental response is consistent with households initially seeking flexible housing in locations that preserve proximity to jobs, schools, and family networks, even when those destinations are not free of environmental risk. The more concentrated sale-price response instead points toward ownership demand shifting to destinations with lower baseline risk relative to the most exposed Phlegraean locations.

This difference also fits the timing of the two adjustment margins. Renting can accommodate precautionary or temporary moves relatively quickly, whereas spatial reallocation—especially when it involves purchasing a home—is a long-run decision shaped by search, financing, transaction costs, and local attachment, consistent with evidence that the economic effects of disaster-induced relocation unfold over extended horizons (Deryugina *et al.*, 2018). Broad rental spillovers may therefore capture an early stage of the adjustment, while the selective sale-price effects are more consistent with the locations in which longer-horizon reallocation has begun to be capitalized. The static estimates cannot establish that the same households generated both responses, so this interpretation remains suggestive.

Finally, the negative sale and rental effects in very-high-risk municipalities outside the Naples province are unlikely to reflect receiving-market pressure. Their distance from the Phlegraean Fields and their high baseline exposure instead make a risk-salience contagion mechanism more plausible: the crisis may have renewed attention to seismic risk in locations that are similar in hazard but are not natural relocation destinations. Overall, the spillover evidence extends the within-zone pattern rather than merely repeating it: proximity and flexibility shape the short-run rental response, while relative safety becomes more visible in the slower ownership margin.

7 Concluding Remarks

This paper studies whether known environmental risk can move markets when it becomes newly vivid, even when measured objective-risk indicators remain comparatively stable. The setting is the 2023 bradyseismic crisis in the Phlegraean Fields, a densely populated volcanic caldera where volcanic and seismic risk had long been monitored, mapped, and publicly recognized before the crisis. The shock sharply increased perceptible earthquakes, media coverage, and public attention, but it did not coincide with catastrophic destruction, fatalities, or an upward shift in the major volcanic alert category. While the crisis generated new signals, the setting comes unusually close to isolating risk salience as an economic force: the main discontinuity was that an existing risk became vivid, local, and decision-relevant.

Our evidence shows that renewed attention can turn known environmental risk into priced economic risk. Sale prices decline in the most exposed Intervention Zone, while rents rise there and across broader affected areas. These patterns are robust across estimators, placebo exercises, and sensitivity checks. We also show that both direct physical salience and media salience help shape the ownership-market response. Complementary demand-and-supply evidence is consistent with a tenure-reallocation mechanism, while heterogeneity and spillover results show that adjustment operates across both tenure and space rather than through a uniform local effect.

The central implication is that awareness and salience are economically distinct. A hazard may be known for decades yet remain only weakly reflected in household choices and market prices, until new signals make it immediate, vivid, and decision-relevant. In that sense, environmental risk affects residential outcomes not only because it exists, but because it becomes salient. While we do not observe beliefs directly, the price patterns are consistent with an increase in the perceived relevance of the hazard, as implied by hedonic revealed-preference logic and supported by survey and media evidence documenting heightened local concern.

The broader relevance of the paper lies in the distinction between latent risk and salient risk. Many places are exposed to hazards that are already mapped and institutionally recognized, yet are not continuously internalized in market behavior. The Phlegraean Fields provide a rare setting in which we can isolate the economic effects of a salience shock from those of disaster realization, abrupt risk reclassification, or new risk disclosure. This specificity is part of what makes the design informative: in many environments, salience, learning, destruction, and policy reclassification arrive together, whereas here the hazard was familiar, physical consequences remained limited, and the main discontinuity was the renewed vividness of the risk. The external validity claim is therefore not that volcanic bradyseism is representative of all hazards, but that many mapped risks—flood, wildfire, seismic, volcanic, industrial, and climate risks—may remain economically latent until attention makes them decision-relevant and actionable.

The policy lesson is not that governments should amplify fear. It is that preparedness policy does not operate only through measuring risk or drafting emergency plans; it also operates through whether known risks are communicated in ways that are credible, locally meaningful, and actionable before disaster occurs. Our results suggest that ex ante salience can matter because it affects the timing and direction of adjustment: some households respond along flexible short-run tenure margins, while others adjust across neighborhoods or municipalities. Policies that aim to reduce exposure therefore need to make protective adjustment feasible, whether through temporary housing support and other short-run tools, or through more durable relocation assistance in highly vulnerable areas.

The goal is not to wait for earthquakes, floods, fires, or media cycles to make risks salient on their own. It is to generate constructive salience ex ante: attention that converts latent awareness into informed, feasible, and orderly adjustment. Public communication, risk maps, drills, official plans, and emergency announcements do not merely transmit information; they can affect the timing and direction of housing choices before physical damage occurs. Salience is therefore both a source of market adjustment and a tool for prevention: it can help households first use flexible short-run margins and, where socially desirable, move toward lower-exposure locations before, rather than after, disasters occur.

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ONLINE APPENDIX

Environmental Risk Salience and Real Estate Markets

Marco Letta Samuel Nocito

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A Additional Figures and Tables

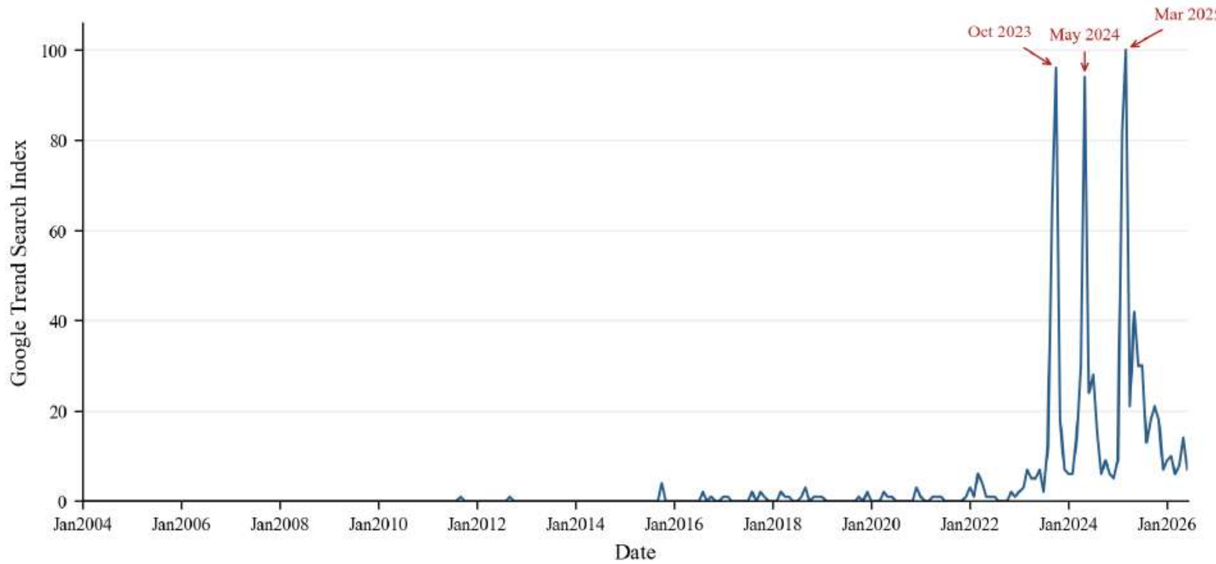
Figure OA.1: Modified Mercalli Intensity (MMI) Scale

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0555	0.232	1.21	3.38	7.46	14.5	26.1	44.4	>72.3
PGV(cm/s)	<0.0178	0.0939	0.686	2.08	5.06	10.9	21.6	40.3	>71.7
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

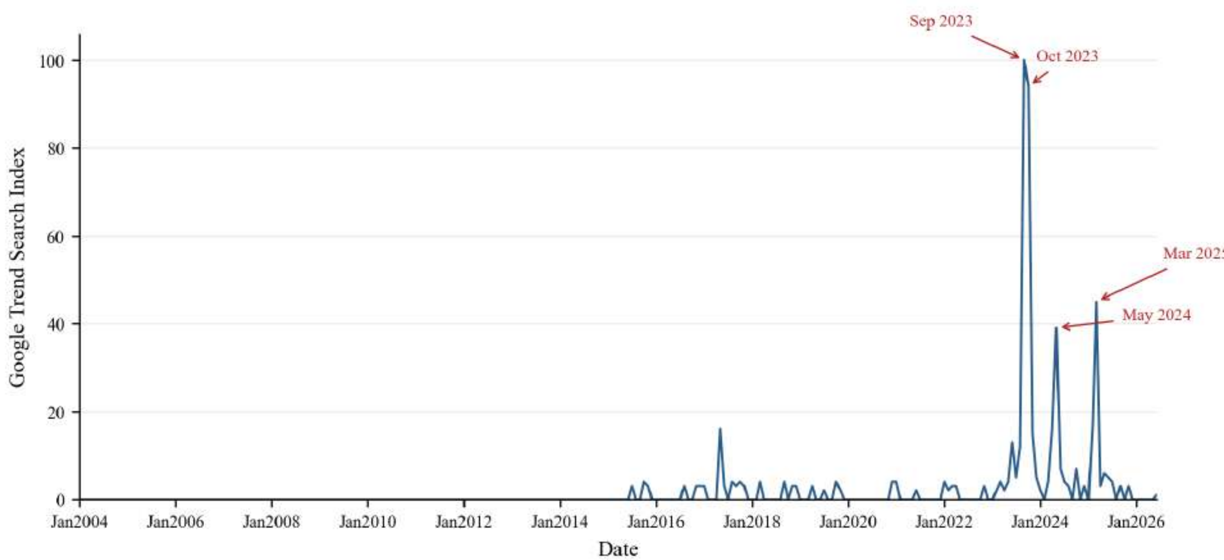
Notes: The figure reports the INGV Modified Mercalli Intensity (MMI) scale of seismic intensity, as displayed on the INGV ShakeMap portal. Source: INGV ShakeMap.

Figure OA.2: Google searches in Campania for terms related to the Phlegraean Fields

Panel A. Searches for "*terremoto Campi Flegrei*"



Panel B. Searches for "*eruzione Campi Flegrei*"

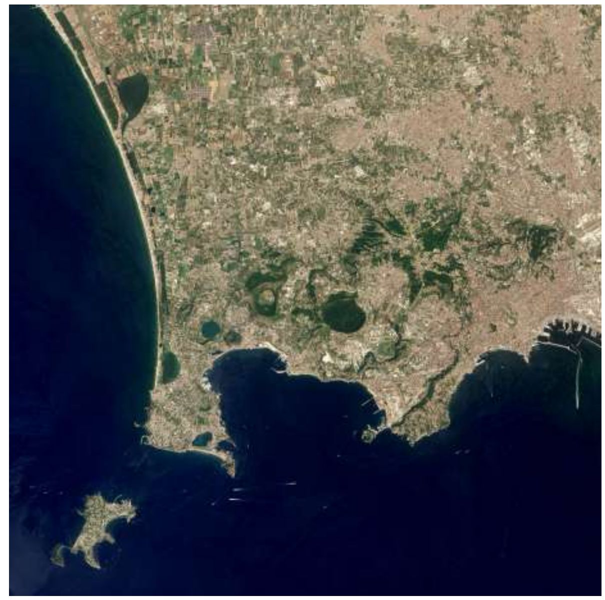


Notes: This figure reports the monthly Google Trends search indices for two queries related to the Phlegraean Fields in Campania, from January 2004 to June 2026. Panel A reports searches for "*terremoto Campi Flegrei*" ("earthquake Phlegraean Fields"), while Panel B reports searches for "*eruzione Campi Flegrei*" ("eruption Phlegraean Fields"). Each index is normalized so that 100 denotes the month with the highest search intensity for the corresponding query over the period. Campania is the geographic scope of the empirical analysis, covering both the treated municipalities and the regional municipalities used to study spillovers. Red arrows mark the main monthly peaks in search intensity. Within Campania, the municipalities with the highest relative search intensity are *Bacoli* for Panel A and *Pozzuoli* for Panel B, the two municipalities forming the core of the Intervention Zone. Updated data are available at: `https://trends.google.it/trends/explore?date=all&geo=IT-72&q=terremoto%20campi%20flegrei,eruzione%20campi%20flegrei&hl=it`.

Figure OA.3: Overview of the Phlegraean Fields

(a) Location of the Phlegraean Fields in Italy

(b) Satellite view of the Phlegraean Fields

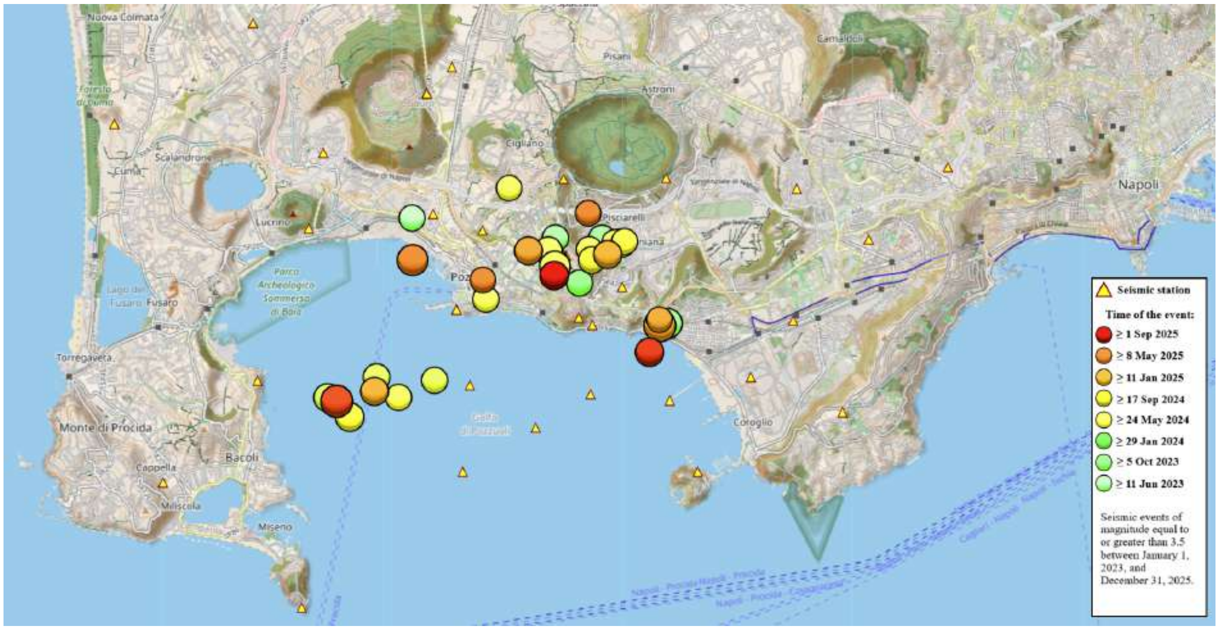


(c) Volcanic activity related to bradyseism

(d) The *Macellum of Pozzuoli*

Notes: This figure shows an overview of the Phlegraean Fields. Panel (a) provides the location of the Phlegraean Fields in Italy, as captured by Google Earth. Panel (b) displays a satellite view of the area, highlighting its dense population. The image comes from NASA's Earth Observatory and is available at: https://earthobservatory.nasa.gov/images/80108/campi-flegrei-italy. Panel (c) illustrates typical volcanic activity in the Phlegraean Fields, which is linked to the bradyseism phenomenon. Panel (d) depicts the *Macellum of Pozzuoli* in *Pozzuoli* (Naples, Italy), an ancient Roman marketplace where traces of marine organisms were found on the building's columns, leading to the discovery and study of the bradyseism phenomenon. The images in Panels (c) and (d) are provided by the Italian National Institute of Geophysics and Volcanology (INGV) and are available at : https://www.ingv.it/newsletter-n-9/3770-bradisismo-una-prova-dell-uniformitarismo-e-del-tempo-profondo and https://www.ov.ingv.it/index.php/il-bradisismo, respectively.

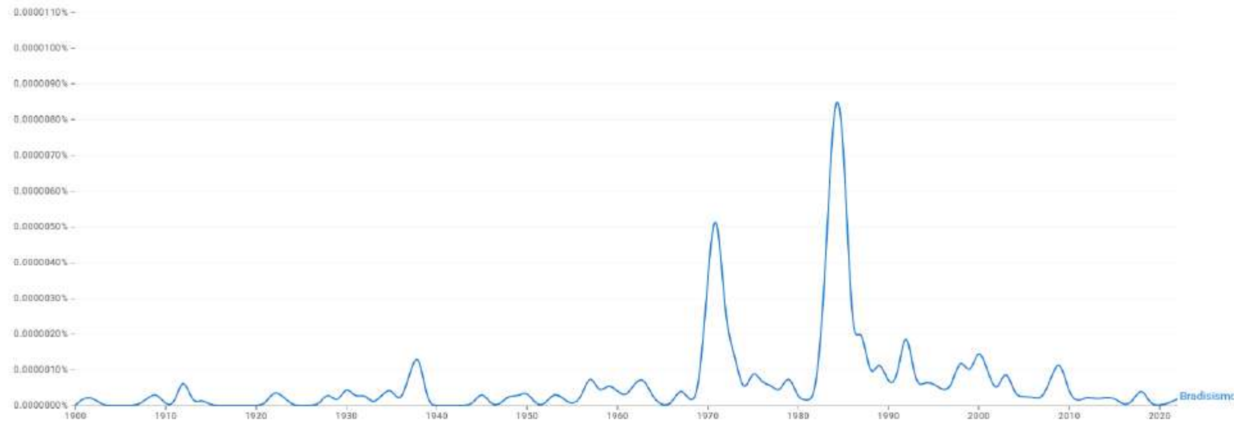
Figure OA.4: The Ongoing Bradyseismic Crisis



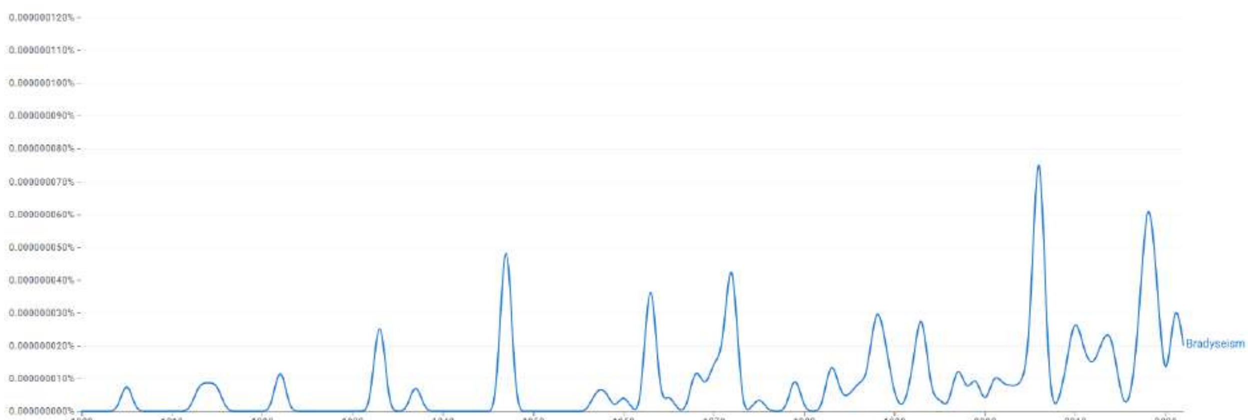
Notes: This figure presents all 31 seismic events in the Phlegraean Fields between January 2023 and December 2025 that registered a magnitude of 3.5 or greater. Prior to September 2023, only two such events were recorded. By contrast, all seven events that reached or exceeded magnitude 4 occurred from September 2023 onward. In this dataset, magnitudes are reported using the duration magnitude (M_d) scale, which is the standard adopted by the Italian National Institute of Geophysics and Volcanology (INGV). A magnitude of 3.5 is commonly considered the threshold at which seismic activity becomes perceptible to the general population. Indeed, the Italian Seismic Bulletin only reports earthquakes with a magnitude equal to or above 3.5: https://bsi.ingv.it/en/terremoti-35. *Source*: Author's query on the data platform provided by the INGV (Ricciolino *et al.*, 2024). The legend has been translated and adapted by the authors; the map can be retrieved at: https://terremoti.ov.ingv.it/gossip/filters.html.

Figure OA.5: Google Books NGrams: Bradyseism in Italian and English books, 1900-2022

(a) *Bradisismo*



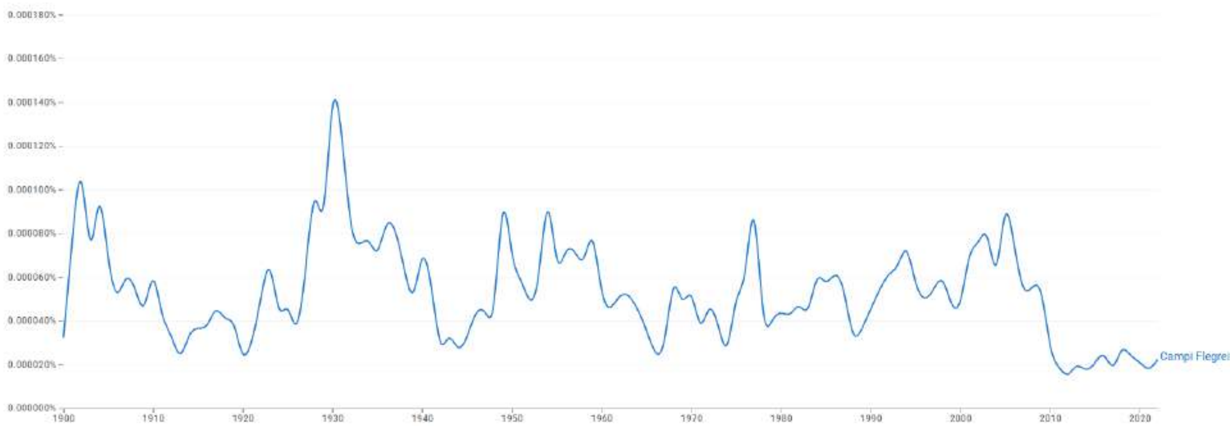
(b) *Bradyseism*



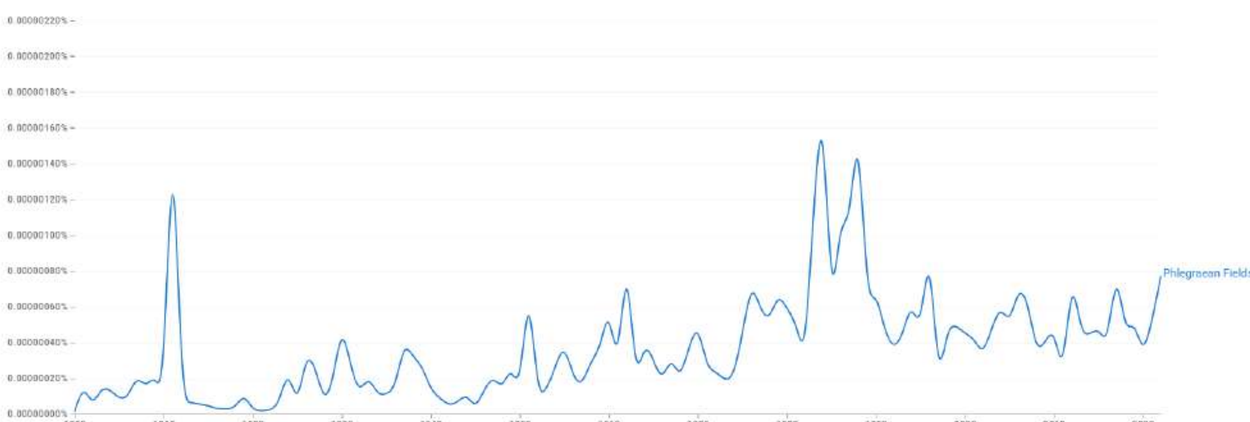
Notes: This figure shows Google Books NGrams data for the Italian language over the period 1900-2022. The series report the relative prevalence of each term, measured as the share of occurrences of the term among all words published in a given year. Panel (a) provides the time series for the term "*Bradisismo*" in Italian books, while Panel (b) displays the corresponding series for "*Bradyseism*" in English books. Panel (c) provides the time series for the term "*Campi Flegrei*" in Italian books, while Panel (d) displays the corresponding series for "*Phlegraean Fields*" in English books. The NGrams count in (upper/lower) case-insensitive. The original data can be downloaded at: https://books.google.com/ngrams/graph?content=&year_start=1900&year_end=2022&corpus=it&smoothing=3.

Figure OA.6: Google Books NGrams: Phlegraean Fields in Italian and English books, 1900-2022

(a) *Campi Flegrei*

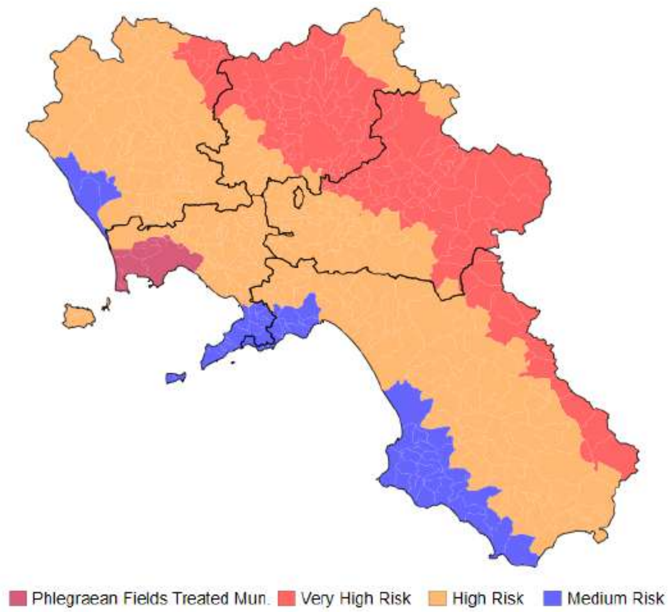


(b) *Phlegraean Fields*



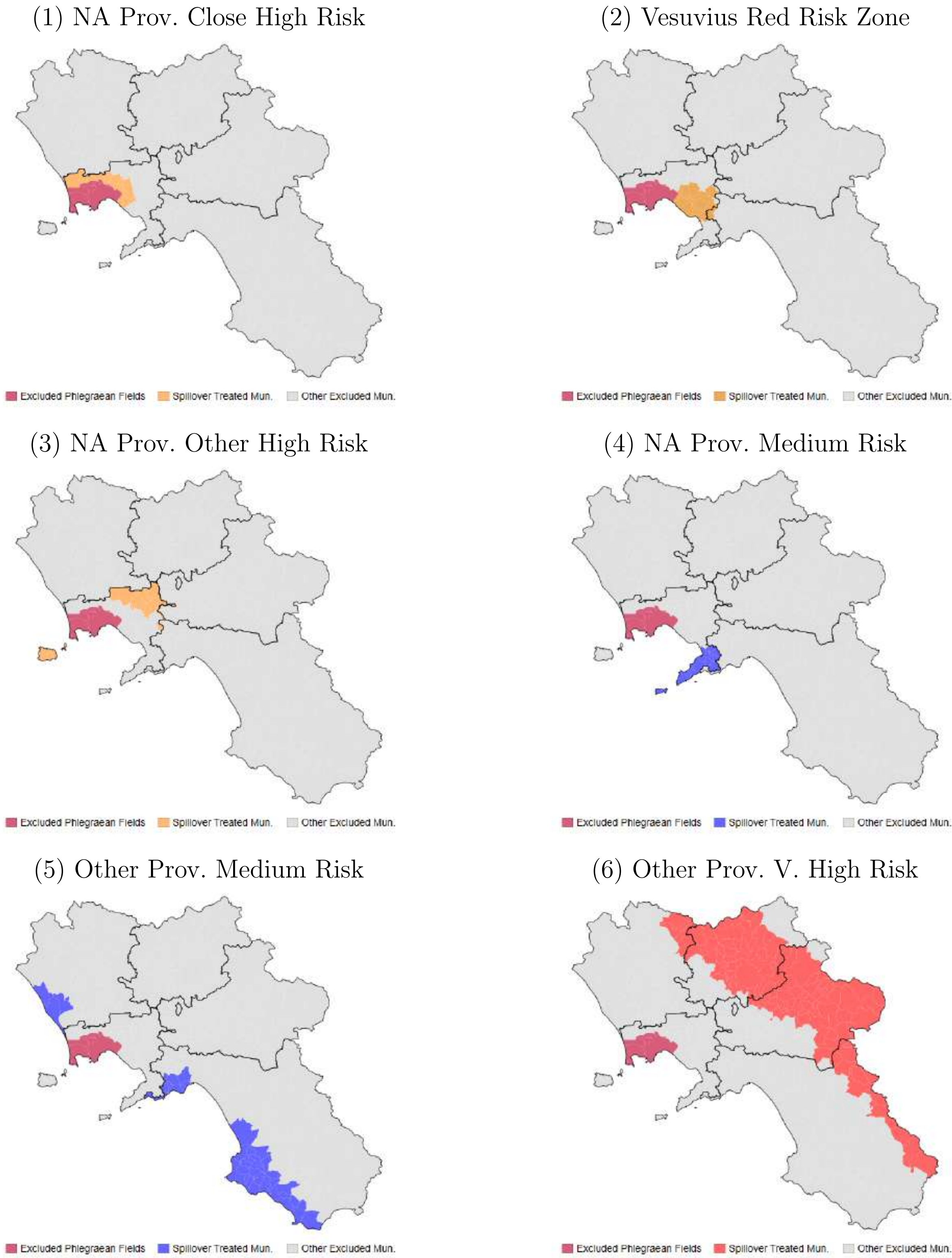
Notes: This figure shows Google Books NGrams data for the Italian language over the period 1900-2022. The series report the relative prevalence of each term, measured as the share of occurrences of the term among all words published in a given year. Panel (a) provides the time series for the term "*Campi Flegrei*" in Italian books, while Panel (b) displays the corresponding series for "*Phlegraean Fields*" in English books. The NGrams count in (upper/lower) case-insensitive. The original data can be downloaded at: https://books.google.com/ngrams/graph?content=&year_start=1900&year_end=2022&corpus=it&smoothing=3.

Figure OA.7: Campania Region - Seismic Risk Zones



Notes: This figure displays the official seismic risk zone classification for municipalities in the Campania region, as defined by the Italian National Institute of Geophysics and Volcanology (INGV) under the 2003 national seismic hazard framework. Municipalities are classified into four zones: Zone 1 (very high seismic risk), Zone 2 (high seismic risk), Zone 3 (medium seismic risk), and Zone 4 (negligible seismic risk). All municipalities belonging to the Phlegraean Fields treatment groups—including those in the Emergency, Red, and Intervention Zones—are classified in Zone 2 (high seismic risk).

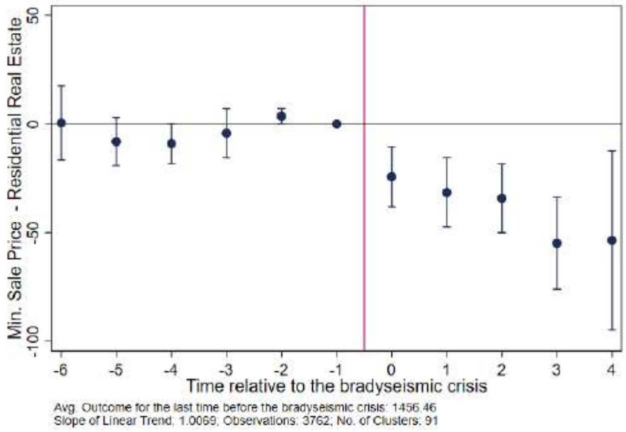
Figure OA.8: Maps of Spillover Treatments

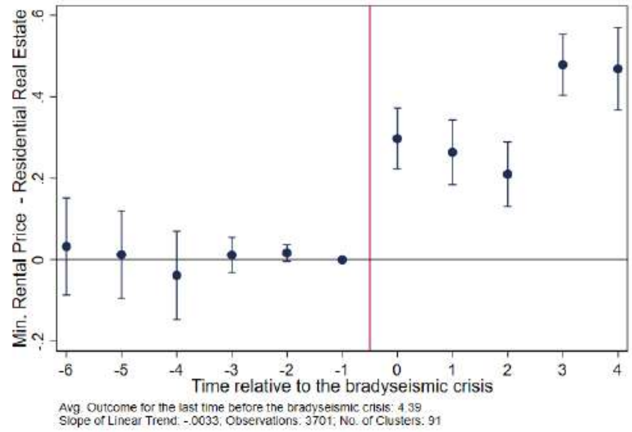


Notes: This figure illustrates the six alternative spillover treatment definitions used in the analysis of Section 6.4. In each panel, cranberry municipalities indicate the Phlegraean Fields municipalities that constitute the primary treatment group of the baseline analysis and are excluded from all spillover specifications. Spillover-treated municipalities are color-coded according to the seismic risk zone classification displayed in Figure OA.7: orange denotes Zone 2 (high seismic risk), red denotes Zone 1 (very high seismic risk), and blue denotes Zone 3 (medium seismic risk). Grey municipalities are excluded from the estimation sample. Panel (1) includes high-risk municipalities in the Naples province that are geographically close to the treated area (*NA Prov. Close High Risk*). Panel (2) isolates municipalities within the official Vesuvius Red Zone, i.e., the highest-risk area surrounding Mount Vesuvius, excluding Naples, Nola, and Pomigliano d'Arco, whose administrative territories only partially overlap with the designated boundary (*Vesuvius Red Risk Zone*). Panel (3) covers other high-risk municipalities in the Naples province not included in Panels (1) or (2) (*NA Prov. Other High Risk*). Panel (4) includes medium-seismic-risk municipalities in the Naples province (*NA Prov. Medium Risk*). Panel (5) covers medium-risk municipalities in Campania provinces other than Naples (*Other Prov. Medium Risk*). Panel (6) includes very-high-seismic-risk municipalities outside the Naples province (*Other Prov. V. High Risk*). Each panel corresponds to a distinct column in Table 4.

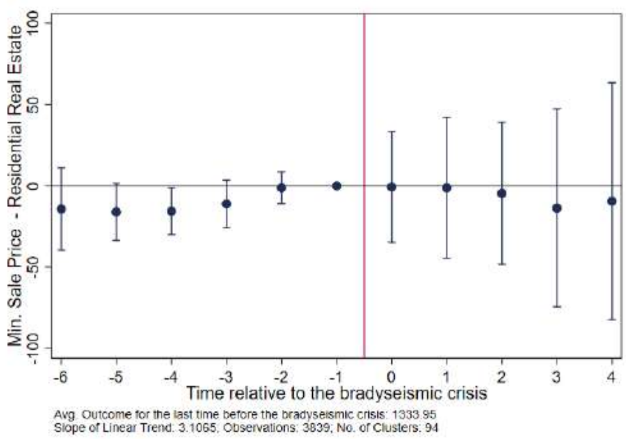
Figure OA.9: Bradyseism and Min. Prices of Residential Real Estate

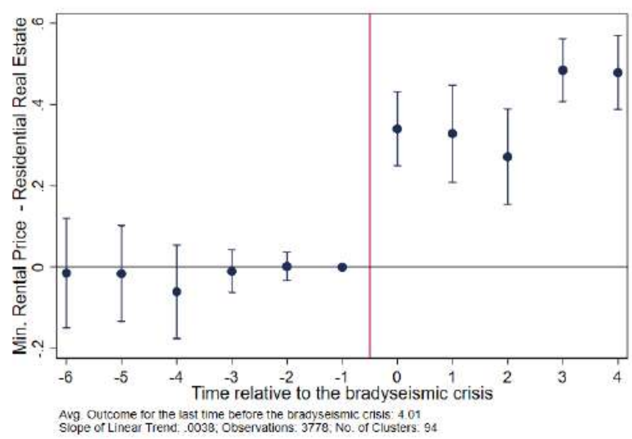
(a) Intervention Zone



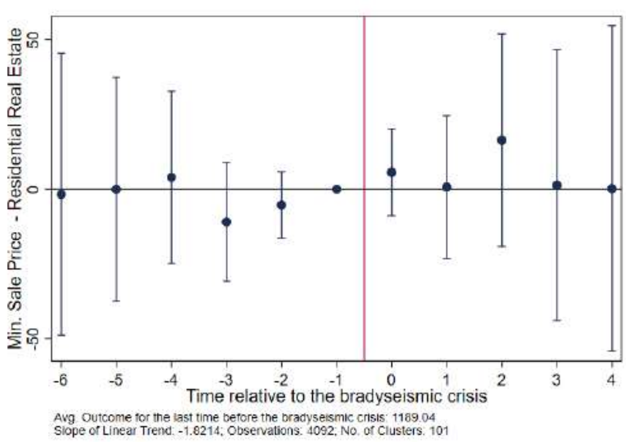


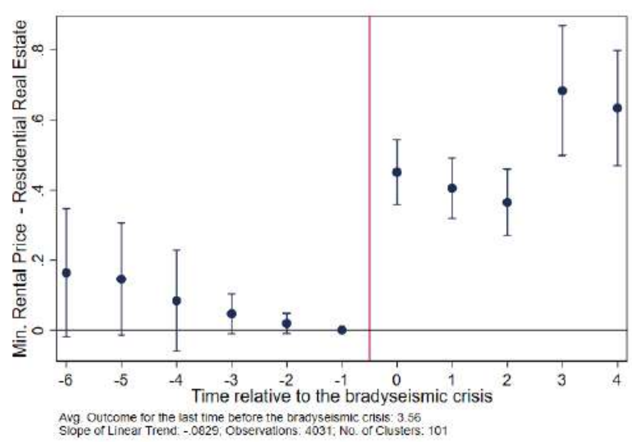
(b) Red Zone





(c) Emergency Zone

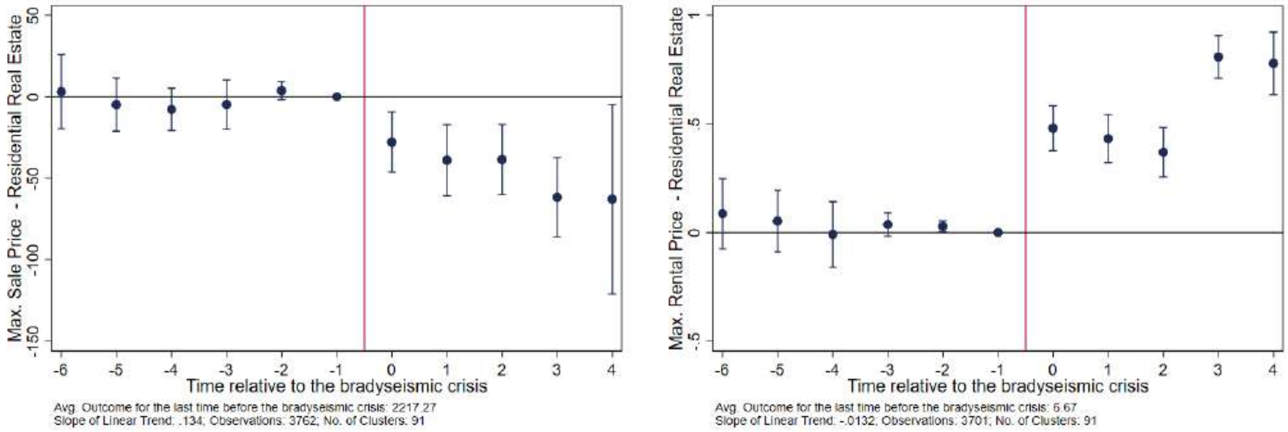




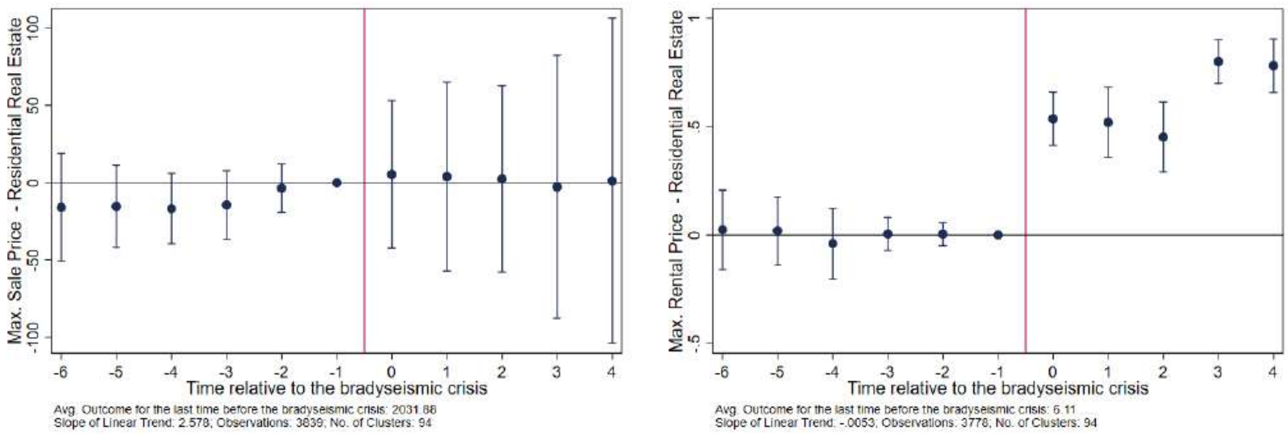
Notes: This figure is organized into three panels—(a) Intervention Zone, (b) Red Zone, and (c) Emergency Zone—corresponding to different treatment definitions described in Section 3.1. Within each panel, the left-hand graph reports the event-study estimates from Equation (1) using the minimum residential real estate sale price as the outcome, while the right-hand graph reports the corresponding estimates for rental prices. Event-study estimates are normalized relative to semester before the bradyseismic crisis. The vertical lines indicate the time of the earthquake (treatment). In the left-hand graphs, regressions control for municipality, semester-year, and residential tier fixed effects; estimates are weighted by the population of each municipality, and 95% confidence intervals are obtained after clustering the standard errors at the municipality level.

Figure OA.10: Bradyseism and Max. Prices of Residential Real Estate

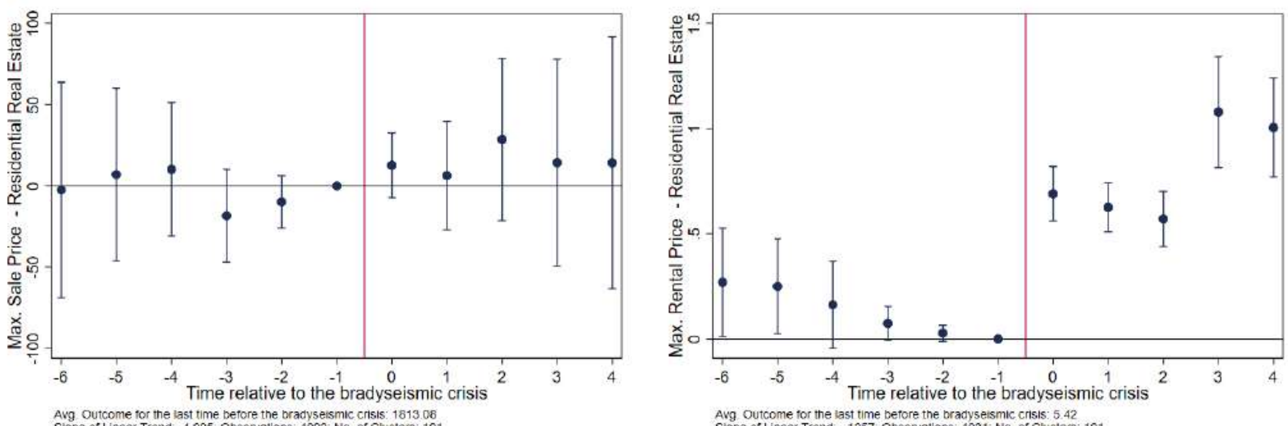
(a) Intervention Zone



(b) Red Zone

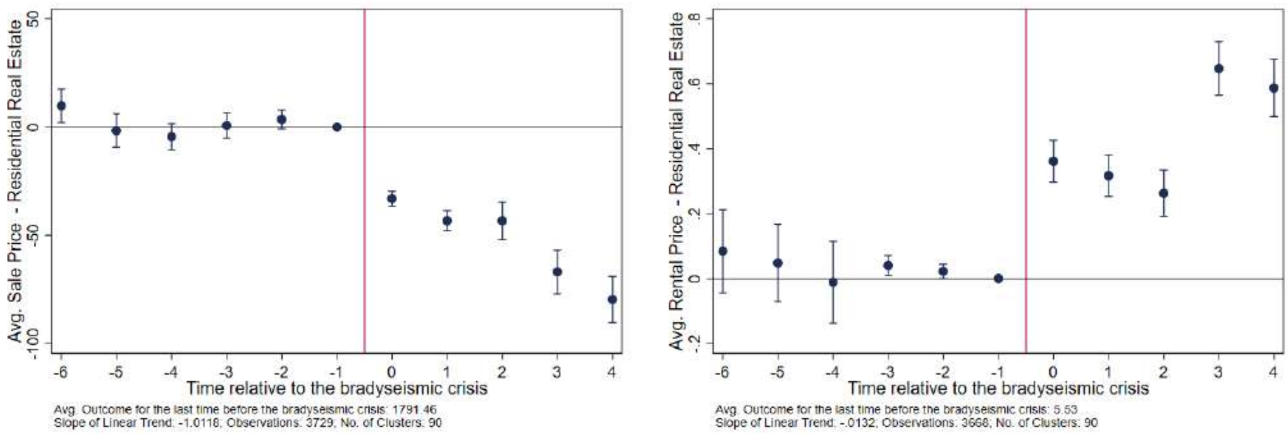


(c) Emergency Zone



Notes: This figure is organized into three panels—(a) Intervention Zone, (b) Red Zone, and (c) Emergency Zone—corresponding to different treatment definitions described in Section 3.1. Within each panel, the left-hand graph reports the event-study estimates from Equation (1) using the maximum residential real estate sale price as the outcome, while the right-hand graph reports the corresponding estimates for rental prices. Event-study estimates are normalized relative to semester before the bradyseismic crisis. The vertical lines indicate the time of the earthquake (treatment). In the left-hand graphs, regressions control for municipality, semester-year, and residential tier fixed effects; estimates are weighted by the population of each municipality, and 95% confidence intervals are obtained after clustering the standard errors at the municipality level.

Figure OA.11: Bradyseism and Avg. Prices - Restricted Intervention Zone



Notes: This figure shows results when using the Restricted Intervention zone treatment definition as described in Section 3.1. Both graphs report event-study estimates from Equation (1). The left-hand graph reports the event-study estimates using the average residential real estate sale price as the outcome, while the right-hand graph reports the corresponding estimates for rental prices. Event-study estimates are normalized relative to semester before the bradyseismic crisis. The vertical lines indicate the time of the earthquake (treatment). Regressions control for municipality, semester-year, and residential tier fixed effects; estimates are weighted by the population of each municipality, and 95% confidence intervals are obtained after clustering the standard errors at the municipality level.

Table OA.1: Timeline of the Current Bradyseismic Crisis in the Phlegraean Fields

Date	**Event**
September 27, 2023 & October 2, 2023	A rise in earthquake frequency during 2023 culminates in two quakes of magnitude 4.2 and 4.0, prompting extraordinary mobilization of the National Civil Protection Service to support the Campania Region. The events are felt by the local population but no damage is reported. The alert level remains yellow, corresponding to the operational phase of "attention", where it has remained since moving from green in 2012.
October 12, 2023	The Italian government approves *Decree-Law No. 140/2023*, titled *"Urgent measures for the prevention of seismic risk related to the bradyseism phenomenon in the Phlegraean Fields area"*, aimed at addressing the ongoing bradyseismic crisis. A new Intervention Zone is established within the Emergency Zone designated in 2016.
December 7, 2023	*Decree-Law No. 140/2023* is formally converted into Law No. 183.
February 26, 2024	Approval of an extraordinary plan for assessing the vulnerability of the built heritage and local seismic risk in the Intervention Zone.
March 25, 2024	Launch of inspections of private residential buildings within the Intervention Zone.
April 22, 2024	Start of the first of three planned emergency drills for 2024 in the Phlegraean area, including school evacuations.
May 20, 2024	A magnitude 4.4 quake strikes the Sulfatara area of *Pozzuoli* municipality. The alert level remains yellow.
March 13, 2025	The strongest quake of the crisis occurs, with a magnitude of 4.6. The earthquake is widely felt; initial assessments report minor damage and one injury due to a collapsed false ceiling. In response, the Campania Region requests renewed extraordinary mobilization of the National Civil Protection Service. A ministerial decree is issued to address the situation.
June 30, 2025	Another major tremor of magnitude 4.6 is registered. No damage is reported. The alert level remains yellow.
October 30, 2025	Decree of the Head of the Civil Protection Department: adoption of an updated alert framework introducing finer sub-states within existing alert levels, refining operational guidance without changes in major alert categories.
November, 4, 2025	Following a Major Risks Commission meeting, the Yellow alert level is confirmed under the updated framework, with enhanced monitoring and preparedness measures.

Source: Italian Civil Protection Department. For a more detailed timeline of the crisis, see https://rischi.protezionecivile.gov.it/en/volcanic/volcanoes-italy/phlegraen-fields/bradyseism-phlegraean-fields/timeline/.

Table OA.2: Italian Seismic Zones: Risk Labels and Official Descriptions

Seismic Zone	**Risk Label**	**Official Description**
1	Very high	Most hazardous zone; the probability that a strong earthquake occurs is high.
2	High	Strong earthquakes are possible.
3	Medium	Strong earthquakes are less likely than in Zones 1 and 2.
4	Negligible	Least hazardous zone; the probability that an earthquake occurs is very low.

Notes: This table reports the seismic zones as defined by the Italian Civil Protection, which classifies municipalities into four levels ranging from 1 to 4. The first column reports the official numerical classification. The second column reports the risk labels that we introduce for exposition but that are not part of the official nomenclature. The third column reports the official description of each seismic zone, translated from Italian into English. Source (official zoning descriptions in Italian): https://rischi.protezionecivile.gov.it/en/pagina-base/classificazione-sismica-0/.

Table OA.3: Data Sources and Main Variables

Source	**Main variables**
OMI	Average sale and rental prices by municipality, residential tier, and semester.
Civil Protection	Emergency Zone, Red Zone, Yellow Zone, and Intervention Zone definitions.
Immobiliare.it	Municipality- and semester-level data on user demand (spending potential) and supply (listings entering); transaction sale prices.
INGV	Peak ground acceleration (PGA) (mean, max, min), number of seismic events, magnitude, timing, location, and Modified Mercalli Intensity (MMI), seismic risk classification of Italian municipalities.
ISTAT	Population, registrations, cancellations, net internal migration flows, geography, and distance measures.
Google Trends	Search intensity for Campi Flegrei-related terms.
ANSA Regional	Regional newspaper articles linked to municipalities using LLM-assisted classification; articles classified as talking about environmental risk, real estate, politics, local politics, sport events, and by sentiment (neutral, fear, reassurance).
SHIW	Tenure status, age, age at purchase/rental entry, region of birth and purchase, earthquake insurance coverage.

Notes: This table reports the main data source used for the analyses.

Table OA.4: Descriptive Statistics

	Mean	SD	Min	Median	Max	N
Panel A: Whole sample						
Avg. Sale Price	1,057.2	387.83	307.5	1,000	3,624.3	4,092
Avg. Rental Price	3.809	1.228	0.000	3.750	11.014	4,031
Panel B: Control Municipalities						
Avg. Sale Price	1,008.3	341.76	307.5	965	2,283.3	3,685
Avg. Rental Price	3.709	1.170	0.000	3.675	8.200	3,624
Panel C: Treated Municipalities - Intervention Zone						
Avg. Sale Price	1,824	321.1	1,229.5	1,958.3	2,269.4	77
Avg. Rental Price	5.775	1.108	3.836	5.733	8.050	77
Panel D: Treated Municipalities - Red Zone						
Avg. Sale Price	1,681	317.43	1,175	1,700	2,269.4	154
Avg. Rental Price	5.301	1.052	3.620	5.200	8.050	154
Panel E: Treated Municipalities - Emergency Zone						
Avg. Sale Price	1,500.5	486.94	875	1,313.3	3,624.3	407
Avg. Rental Price	4.698	1.373	2.917	4.217	11.014	407

Notes: This table reports summary statistics for the main outcomes. The sample is a panel at the municipality-tier and semester-year levels, covering the period from the second semester of 2020 through the second semester of 2025. The first earthquake marking the onset of the bradyseismic crisis occurred in September 2023. Panel A reports statistics for the full sample. Panel B focuses on municipalities not affected by the bradyseismic crisis (controls). Panels C, D, and E present statistics for municipalities in the Intervention Zone, in the Red Zone, and in the Emergency Zone, respectively. For the visualization and formal definitions of these zones, see Figure 2 and Section 3.1.

Table OA.5: National Attention to the Phlegraean Fields Crisis, by Region

Panel A. Term: "terremoto Campi Flegrei"		
Rank	Region	Index
1	Campania	100
2	Molise	12
3	Abruzzo	9
4	Lazio	9
5	Basilicata	8
6	Umbria	7
7	Apulia	5
8	Calabria	5
9	Emilia-Romagna	5
10	Marche	5
11	Trentino-South Tyrol	5
12	Tuscany	5
13	Friuli-Venezia Giulia	4
14	Liguria	4
15	Lombardy	4
16	Piedmont	3
17	Sardinia	3
18	Sicily	3
19	Veneto	3
20	Aosta Valley	0

Panel B. Term: "eruzione Campi Flegrei"		
Rank	Region	Index
1	Campania	100
2	Molise	24
3	Basilicata	22
4	Lazio	20
5	Abruzzo	19
6	Liguria	16
7	Marche	16
8	Umbria	15
9	Apulia	14
10	Emilia-Romagna	14
11	Tuscany	14
12	Friuli-Venezia Giulia	12
13	Lombardy	12
14	Piedmont	12
15	Calabria	11
16	Veneto	11
17	Sicily	10
18	Sardinia	9
19	Trentino-South Tyrol	8
20	Aosta Valley	0

Notes: This table reports Google Trends regional search intensity within Italy for the terms "*terremoto Campi Flegrei*" and "*eruzione Campi Flegrei*" over July 1, 2020 to December 31, 2025. Google Trends rescales each query separately so that the region with the highest search intensity takes value 100. A blank entry in the Google Trends export is treated as zero, indicating insufficient search volume. Full data links: `https://trends.google.it/trends/explore?date=2020-07-01%202025-12-31&geo=IT&q=terremoto%20campi%20flegrei&hl=it`; `https://trends.google.it/trends/explore?date=2020-07-01%202025-12-31&geo=IT&q=eruzione%20campi%20flegrei&hl=it`.

Table OA.6: Cumulative Formal Mobility Flows in the Intervention Zone

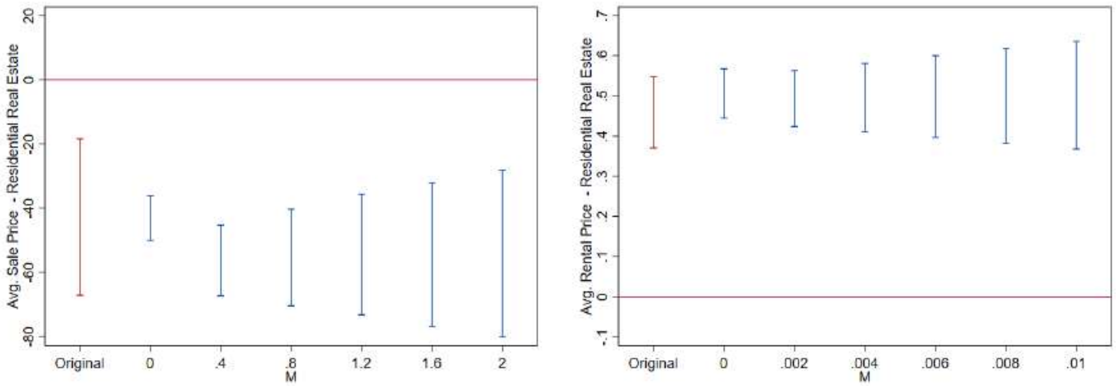
	Pre-crisis Total	Post-crisis Total	Change	Before–after % change
Panel A: *Cumulative flows*				
Registrations from other municipalities	3,916	3,787	-129	-3.3%
Cancellations to other municipalities	5,019	5,593	574	11.4%
Net internal migration	-1,103	-1,806	-703	-63.7%
Panel B: *Flows as % of pre-crisis population*				
Registrations from other municipalities	3.85%	3.72%	-0.13 p.p.	
Cancellations to other municipalities	4.93%	5.49%	0.56 p.p.	
Net internal migration	-1.08%	-1.77%	-0.69 p.p.	

Notes: The table reports cumulative municipal registry flows for *Pozzuoli* and *Bacoli*, which form the core of the Intervention Zone. The pre-crisis period covers the 27 months immediately preceding the onset of the crisis, from July 2021 to September 2023. This choice makes the pre- and post-crisis windows symmetric and excludes the period most directly affected by COVID-19 mobility restrictions, which in Italy were progressively relaxed until June 2021. The post-crisis period covers the 27 months following the onset of the crisis, from October 2023 to December 2025. Net internal migration is defined as registrations from other Italian municipalities minus cancellations to other Italian municipalities. Panel B reports the same quantities as shares of the average pre-crisis population of *Pozzuoli* and *Bacoli*. Percentage-point changes are reported in the "Change" column. For net internal migration, the before–after percentage change is computed relative to the absolute value of the pre-crisis balance, so the negative sign indicates a deterioration of the migration balance. Source: authors' calculations from ISTAT monthly municipal demographic balance data.

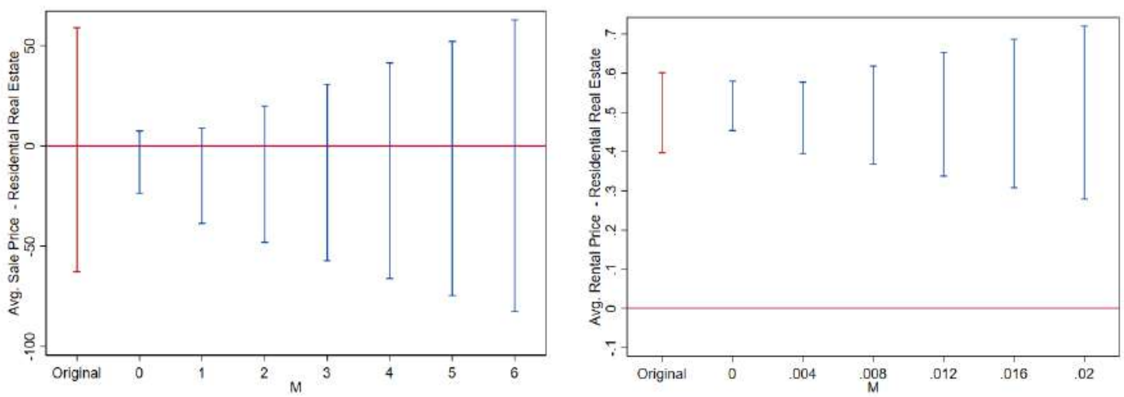
B Additional Robustness Checks

Figure OA.12: Honest Bounds of Rambachan and Roth (2023) - Avg. Prices

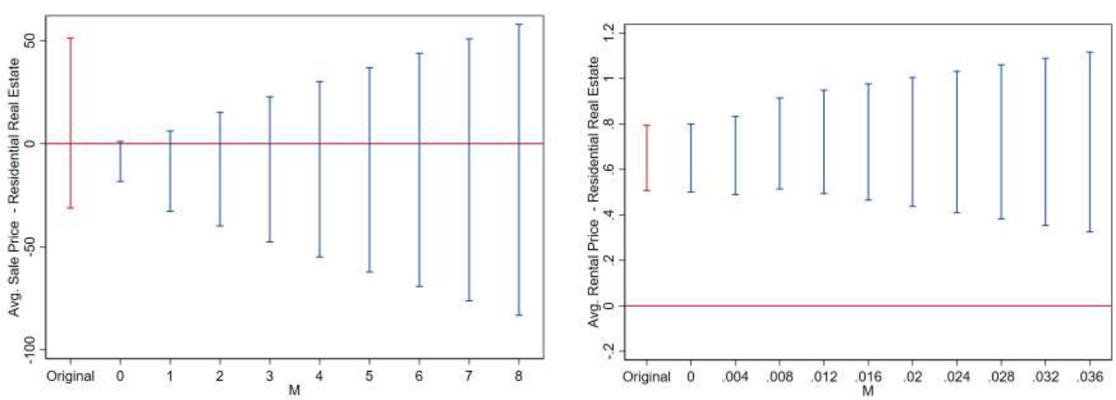
(a) Intervention Zone



(b) Red Zone



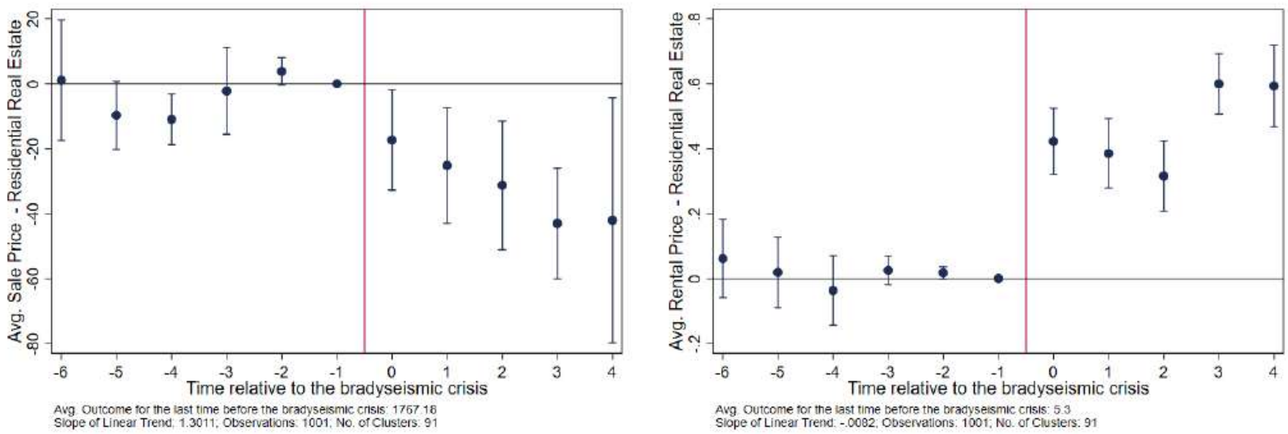
(c) Emergency Zone



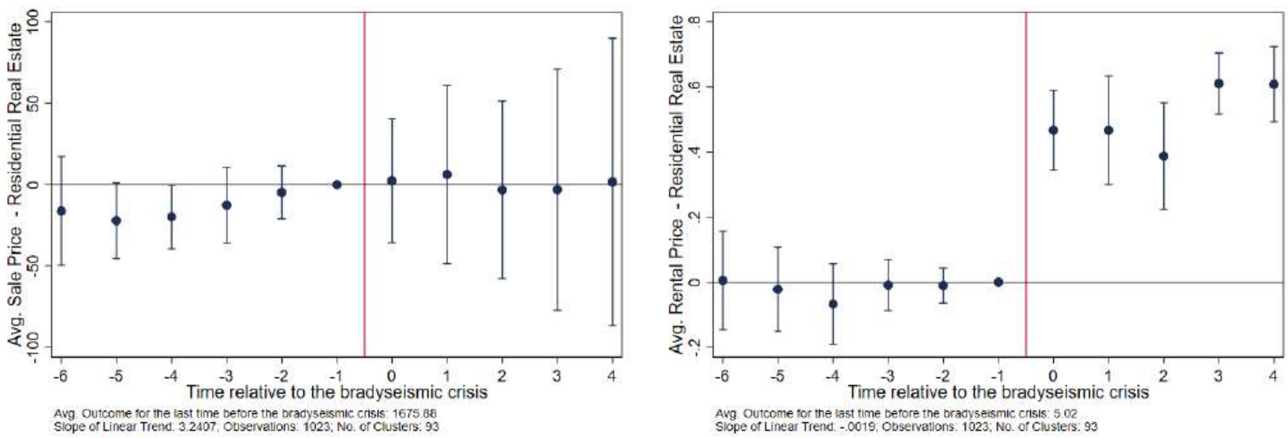
Notes: This figure reports the confidence sets described in Rambachan and Roth (2023) for the average of all post-crisis coefficients on the outcomes described in Figure 4, when we allow the slope of the pre-trend coefficients to change by no more than M—reported on the x-axis—across consecutive periods. Values of $M = 0$ correspond to cases where differences between treated and control are exactly linear.

Figure OA.13: Bradyseism and Avg. Prices of Residential Real Estate - Municipality Panel

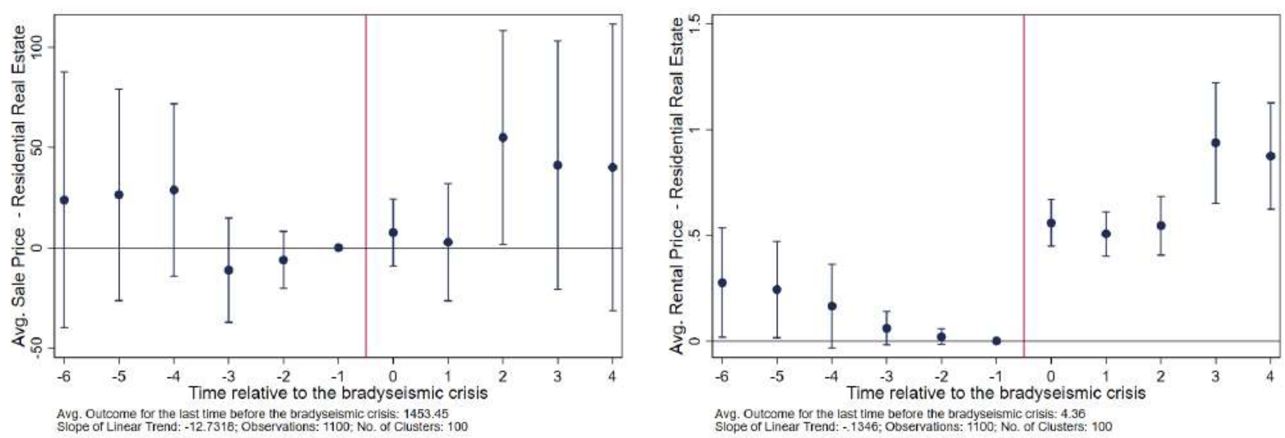
(a) Intervention Zone



(b) Red Zone



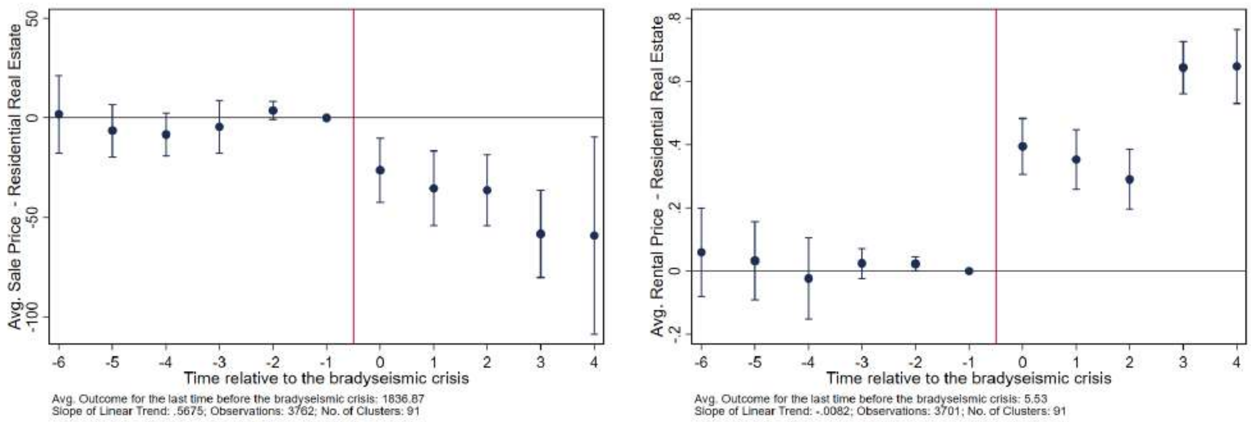
(c) Emergency Zone



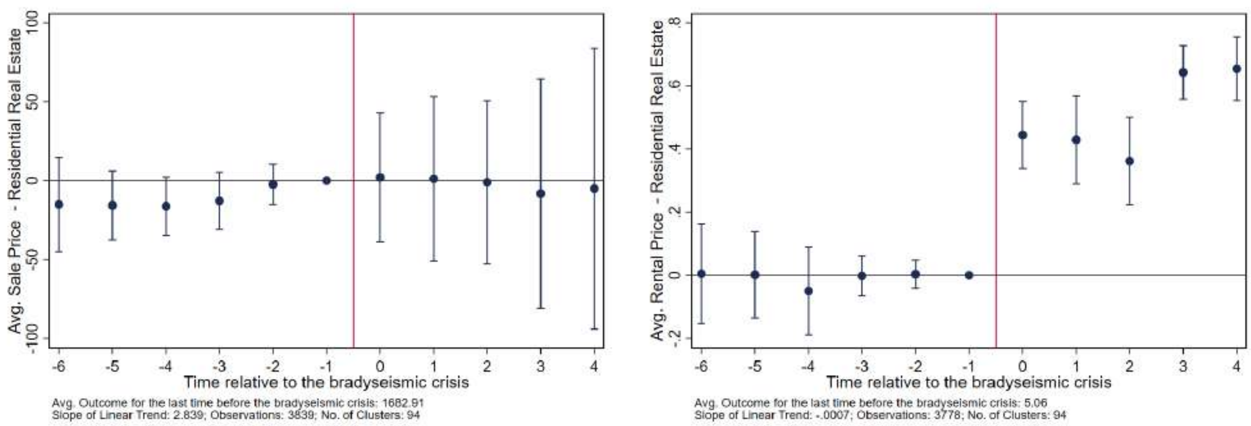
Notes: This figure is organized into three panels—(a) Intervention Zone, (b) Red Zone, and (c) Emergency Zone—corresponding to different treatment definitions described in Section 3.1. Within each panel, the left-hand graph reports the event-study estimates from Equation (1) using the average residential real estate sale price as the outcome, while the right-hand graph reports the corresponding estimates for rental prices. Event-study estimates are normalized relative to semester before the bradyseismic crisis, and are estimated on a municipality–semester panel. The vertical lines indicate the time of the earthquake (treatment). Regressions control for municipality, semester-year, and residential tier fixed effects; estimates are weighted by the population of each municipality, and 95% confidence intervals are obtained after clustering the standard errors at the municipality level.

Figure OA.14: Bradyseism and Avg. Prices of Residential Real Estate – With Tourism Controls

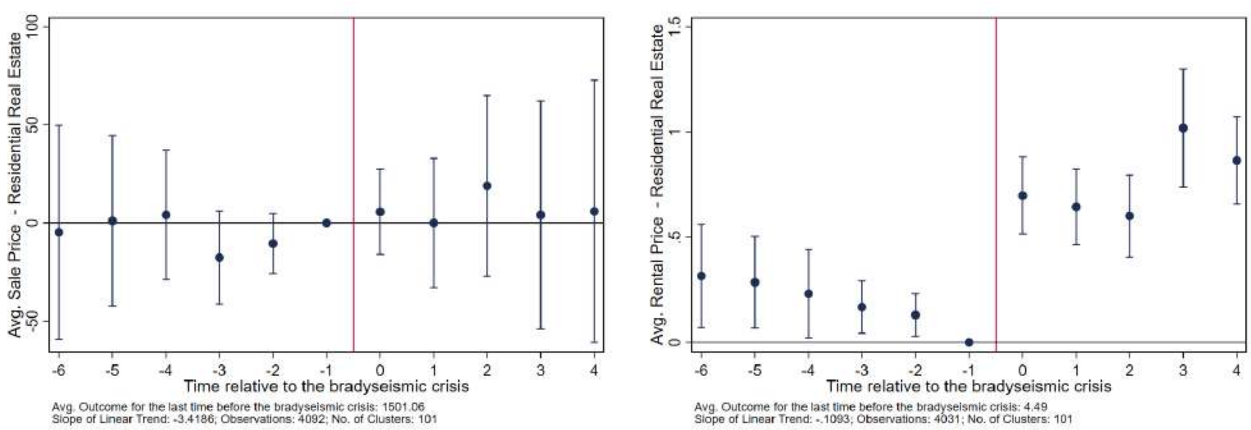
(a) Intervention Zone



(b) Red Zone



(c) Emergency Zone



Notes: This figure is organized into three panels—(a) Intervention Zone, (b) Red Zone, and (c) Emergency Zone—corresponding to different treatment definitions described in Section 3.1. Within each panel, the left-hand graph reports the event-study estimates from Equation (1) using the average residential real estate sale price as the outcome, while the right-hand graph reports the corresponding estimates for rental prices. Event-study estimates are normalized relative to semester before the bradyseismic crisis. The vertical lines indicate the time of the earthquake (treatment). Regressions control for municipality-level tourism visits divided by 100,000, municipality, semester-year, and residential tier fixed effects; estimates are weighted by the population of each municipality, and 95% confidence intervals are obtained after clustering the standard errors at the municipality level.

Table OA.7: Static DiD and SDID - Bradyseism and *Immobiliare.it* Transaction Sale Prices

	Intervention Zone	Red Zone	Emergency Zone
	Transaction sale price	Transaction sale price	Transaction sale price
	(1)	(2)	(3)
Panel A: Static DiD Estimator			
Treatment	-158.251^{***}	-70.412	-45.661
	(28.488)	(43.811)	(29.685)
Observations	999	1,032	1,109
Avg. outcome pre-period	1,756.75	1,534.20	1,411.86
Outcome SD pre-period	186.03	267.76	310.54
Adjusted R^2	0.912	0.910	0.949
DiD Model Fixed Effects:			
Municipality FE	YES	YES	YES
Semester-year FE	YES	YES	YES
Panel B: Static SDID Estimator			
Treatment	-179.484^{**}	-45.344	-31.303
	(74.281)	(63.457)	(30.726)
Observations	990	1,023	1,100
Avg. outcome pre-period	1,756.75	1,534.20	1,411.86
Outcome SD pre-period	186.03	267.76	310.54

Notes: This table reports static treatment effects for the average transaction sale price from *Immobiliare.it*, measured at the municipality-semester level in euro per square meter. Columns (1)–(3) use the Intervention Zone, Red Zone, and Emergency Zone treatment definitions, respectively. Panel A reports estimates from a static DiD specification with municipality and semester-year fixed effects; standard errors are clustered at the municipality level. Panel B reports estimates from static SDID specifications with bootstrap standard errors based on 500 replications. Pre-period means and standard deviations are calculated on the DiD estimation sample of treated units only. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

B.1 Random Inference Analyses

We implement a placebo test, which is a key instrument for evaluating the robustness of observational studies (Eggers *et al.* (2024)), to rule out the possibility of spurious findings and to strengthen the credibility of our research design. Specifically, we apply the type of placebo test used in Belloc *et al.* (2016), which follows the logic of randomization inference by randomly reassigning the treatment indicator across the sample, excluding residential tiers from municipalities that belong to the actually treated zones. We then re-run the empirical analysis 1,000 times using this permuted assignment and examine the resulting distribution of effects relative to our main estimates.

This approach is particularly well-suited to our setting, where treatment is assigned at the cluster level and the number of treated clusters is modest (Conley and Taber (2011); MacKinnon and Webb (2020); Roth *et al.* (2023)). In settings with a modest number of treated clusters, randomization-inference-style placebo tests are more compelling than relying solely on wild cluster bootstrap methods: conventional cluster-robust inference may be unreliable, and even different variants of the wild cluster bootstrap can either overreject or underreject substantially (MacKinnon and Webb (2020)). By contrast, randomization inference maps directly into the logic of our treatment reassignment exercise and provides a more credible finite-sample benchmark for statistical significance.

Randomization Inference Tests (RITs) estimate how extreme the observed effect is relative to a distribution of placebo effects generated by reassigning the treatment. This also provides a non-parametric robustness check against finite sample bias, relying solely on the treatment permutations rather than asymptotic inference (Young (2019); Dell and Olken (2020)). Specifically, we estimate placebo counterfactuals by randomly and fictitiously attributing the treatment in the actual semester-year t (i.e., second semester of 2023) to a number of municipalities equal to the size of the treated group in each reference zone—two for the Intervention Zone, five for the Red Zone, and eleven for the Emergency Zone—always excluding the actually treated municipalities from the analysis. These counterfactual estimates allow us to compute a randomization inference (RI) p-value, defined as the proportion of placebo coefficients that are more extreme than the observed baseline coefficient in the direction of the observed effect. Formally,

$$p_j = \frac{1}{N} \sum_{k=1}^{N} \mathbb{1} \left\{ \operatorname{sgn}(\hat{\beta}_{j,\mathrm{obs}})\, \beta_{j,k} > \operatorname{sgn}(\hat{\beta}_{j,\mathrm{obs}})\, \hat{\beta}_{j,\mathrm{obs}} \right\}$$

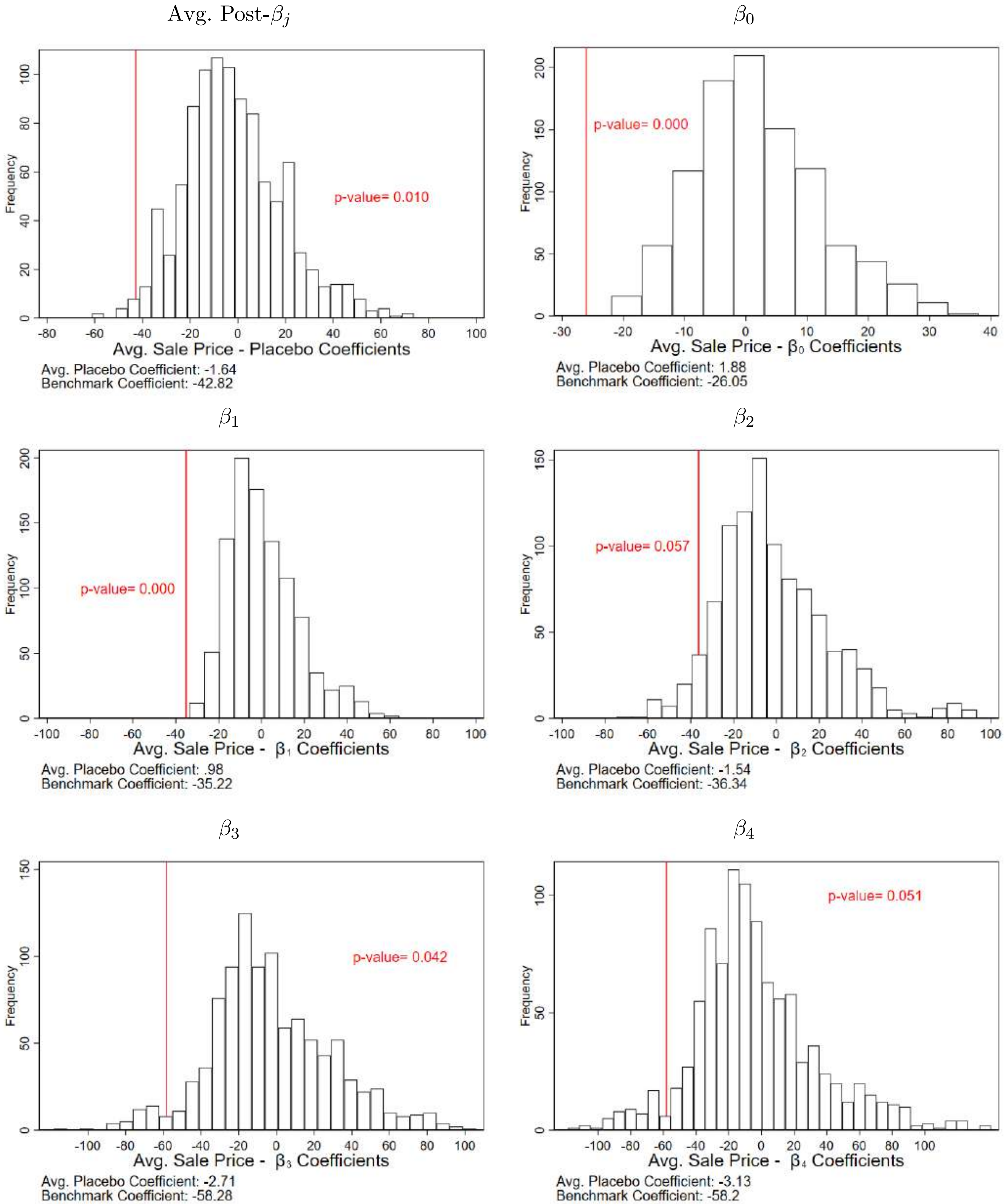
$\forall j \in [0, 1, 2, 3, 4]$ with $N = 1{,}000$, where $\beta_{j,k}$ denotes the coefficients j obtained through permutations, and $\hat{\beta}_{j,obs}$ is the observed benchmark coefficient j.

Appendix Figures OA.15 and OA.16 for the Intervention Zone treatment, report in each panel, from top-right to the bottom-right, the graphs for the post-treatment coefficients β_0, β_1, β_2, β_3, and β_4 of Equation (1). The top-left graph shows the average of the post-treatment β_j. Appendix Figures OA.17 and OA.18 present the same analysis for the Red Zone, while Appendix Figures OA.19 and OA.20 relate to the Emergency Zone. The figure also plots the distribution of estimated placebo coefficients, displaying the observed benchmark coefficient as a red vertical line.

The RI p-values provide statistical inference consistent with the benchmark results shown in Figure 4, with some improvement in statistical significance for the β_0 and β_2 coefficients of the average sale price when we use inclusion in the Emergency Zone as treatment. In all specifications, the benchmark coefficient is substantially larger than the average of placebo coefficients, with the latter being economically negligible in magnitude—on average, the benchmark estimate is approximately 15 to 20 times larger in absolute value than the average placebo coefficient for sale prices, while for rental prices the average placebo coefficient is virtually indistinguishable from zero across all treatment definitions and post-treatment periods.

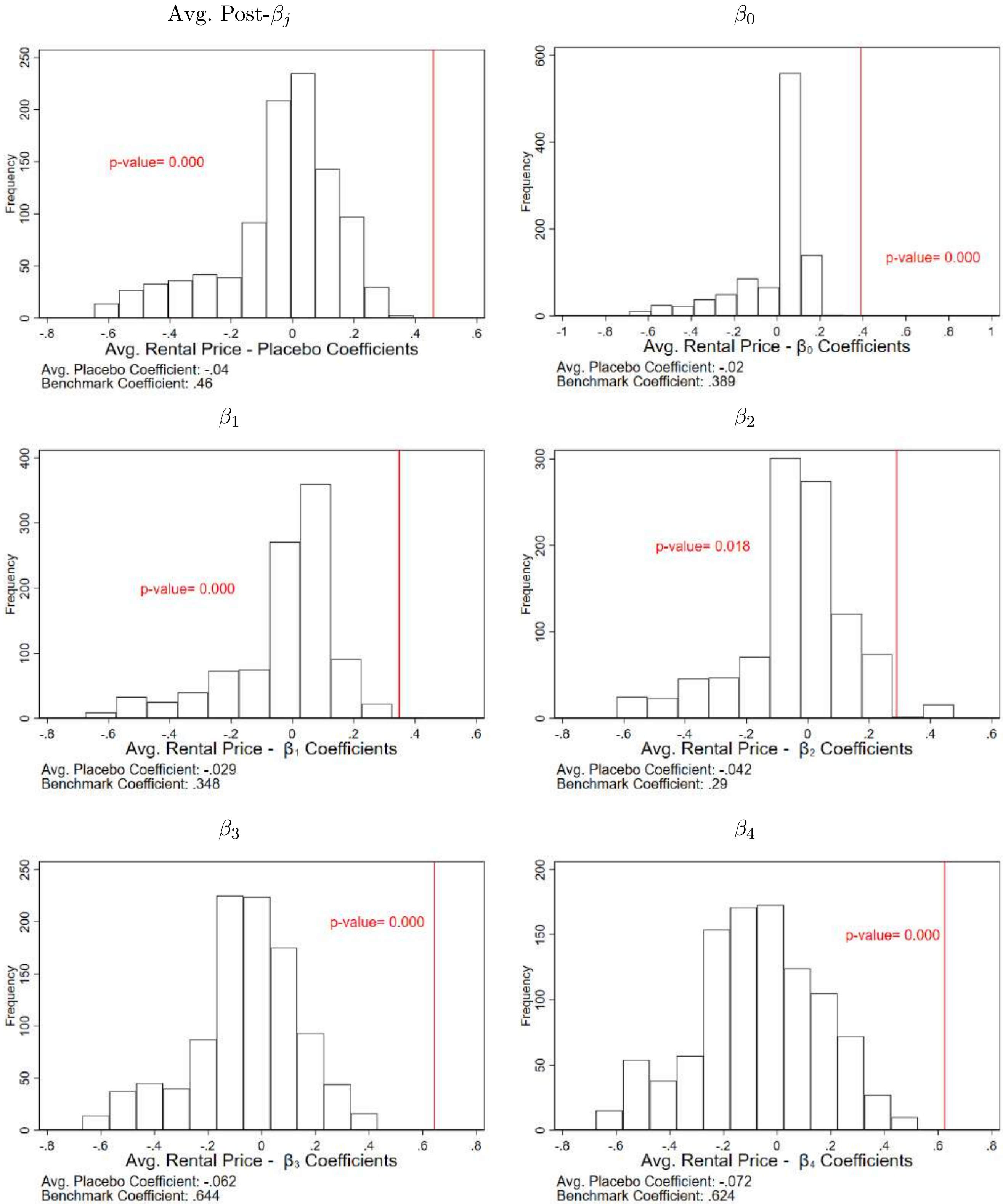
A related implication of these randomization tests is that the estimated effects do not appear to reflect a broader national response among seismically exposed municipalities. When treatment is reassigned to untreated municipalities outside Campania with comparable seismic risk, the placebo distribution remains centered close to zero. This pattern is consistent with a localized market response, rather than nationwide effects of the Phlegraean salience shock or a generalized repricing of seismic risk in other high-risk areas.

Figure OA.15: RIT - Avg. Sale Price of Residential Real Estate - Intervention Zone Treatment



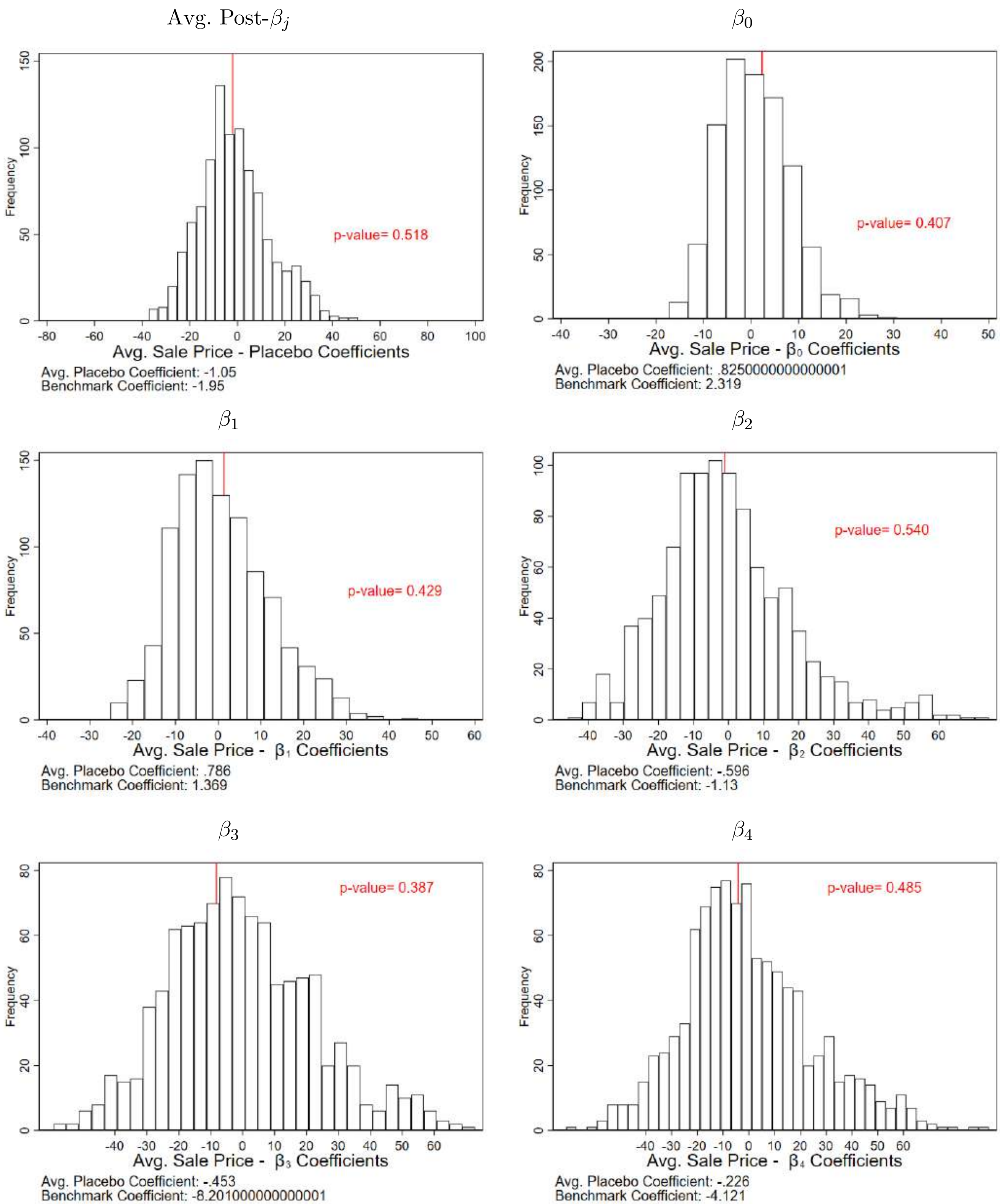
Notes: Each graph plots the distribution of 1,000 event-study placebo estimates for the Intervention Zone, using as a dependent variable the average sale price of residential real estate. In each panel, from the top-right to the bottom-right, figure shows the graphs relative to the post-treatment coefficients β_0, β_1, β_2, β_3, and β_4 of Equation (1), respectively. The top-left graph shows the same exercise for the average of the post-treatment β_j coefficients. Regressions control for municipality, semester-year, and residential tier fixed effects. Event-study estimates are normalized relative to semester before the bradyseismic crisis. We estimate placebo counterfactuals by randomly and fictitiously assigning the treatment to a number of municipalities equal to the size of the actual treated group—i.e., two for the Intervention Zone—always excluding the actually treated municipalities from the analysis. The RI p-value is calculated as the proportion of placebo coefficients that are more extreme than the observed baseline coefficient for the corresponding treatment group, shown as a red vertical line and corresponding to the estimates reported in Figure 4, left-hand graphs. The RIT p-value formula is defined in Section B.1. Below the graph on the left, we report the average placebo coefficient, and the benchmark coefficient.

Figure OA.16: RIT - Avg. Rental Price of Residential Real Estate - Intervention Zone Treatment



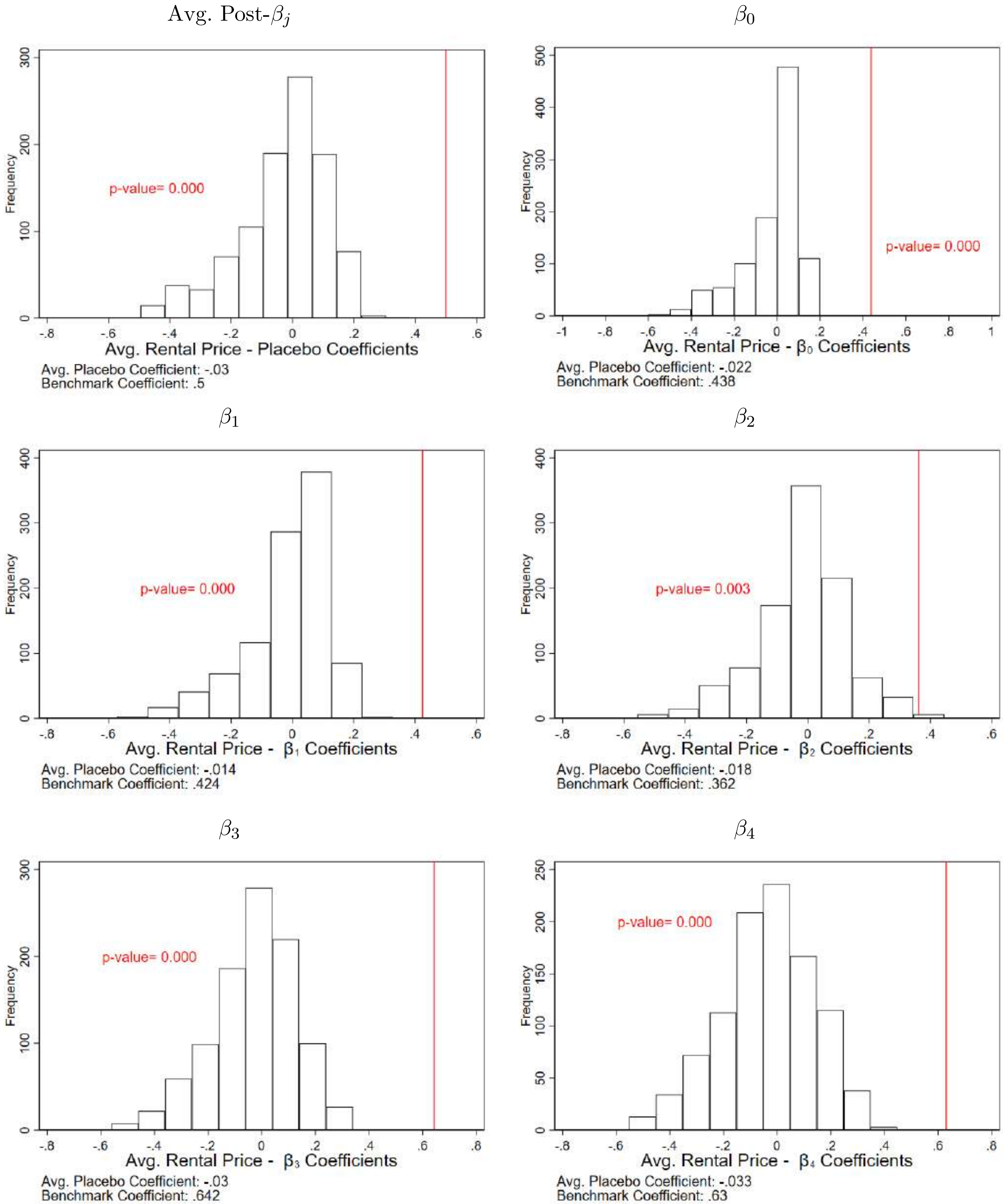
Notes: Each graph plots the distribution of 1,000 event-study placebo estimates for the Intervention Zone, using as a dependent variable the average rental price of residential real estate. In each panel, from the top-right to the bottom-right, figure shows the graphs relative to the post-treatment coefficients β_0, β_1, β_2, β_3, and β_4 of Equation (1), respectively. The top-left graph shows the same exercise for the average of the post-treatment β_j coefficients. Regressions control for municipality, semester-year, and residential tier fixed effects. Event-study estimates are normalized relative to semester before the bradyseismic crisis. We estimate placebo counterfactuals by randomly and fictitiously assigning the treatment to a number of municipalities equal to the size of the actual treated group—i.e., two for the Intervention Zone—always excluding the actually treated municipalities from the analysis. The RI p-value is calculated as the proportion of placebo coefficients that are more extreme than the observed baseline coefficient for the corresponding treatment group, shown as a red vertical line and corresponding to the estimates reported in Figure 4, left-hand graphs. The RIT p-value formula is defined in Section B.1. Below the graph on the left, we report the average placebo coefficient, and the benchmark coefficient.

Figure OA.17: RIT - Avg. Sale Price of Residential Real Estate - Red Zone Treatment



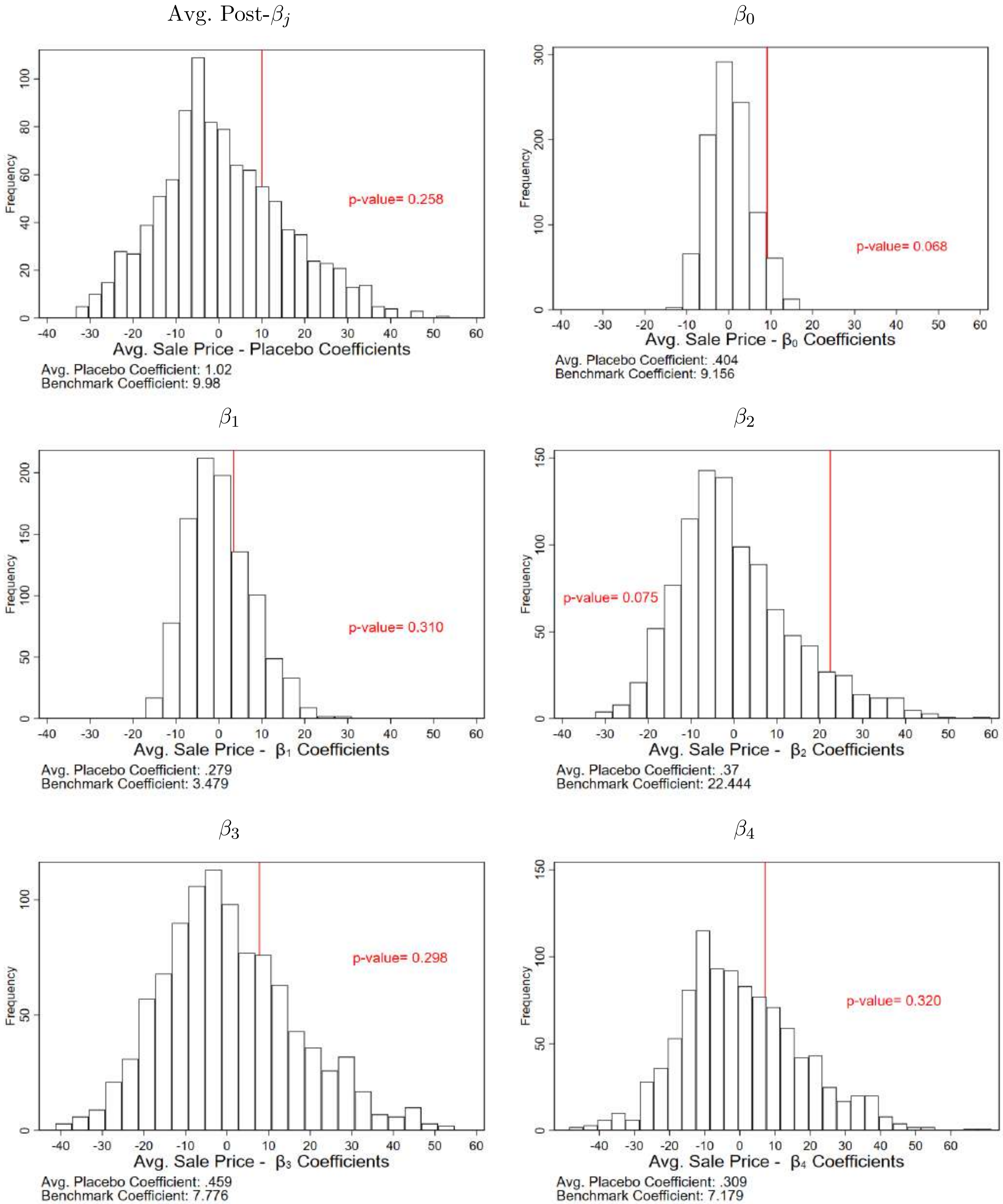
Notes: Each graph plots the distribution of 1,000 event-study placebo estimates for the Red Zone, using as a dependent variable the average sale price of residential real estate. In each panel, from the top-right to the bottom-right, figure shows the graphs relative to the post-treatment coefficients β_0, β_1, β_2, β_3, and β_4 of Equation (1), respectively. The top-left graph shows the same exercise for the average of the post-treatment β_j coefficients. Regressions control for municipality, semester-year, and residential tier fixed effects. Event-study estimates are normalized relative to semester before the bradyseismic crisis. We estimate placebo counterfactuals by randomly and fictitiously assigning the treatment to a number of municipalities equal to the size of the actual treated group—i.e., five for the Red Zone—always excluding the actually treated municipalities from the analysis. The RI p-value is calculated as the proportion of placebo coefficients that are more extreme than the observed baseline coefficient for the corresponding treatment group, shown as a red vertical line and corresponding to the estimates reported in Figure 4, left-hand graphs. The RIT p-value formula is defined in Section B.1. Below the graph on the left, we report the average placebo coefficient, and the benchmark coefficient.

Figure OA.18: RIT - Avg. Rental Price of Residential Real Estate - Red Zone Treatment



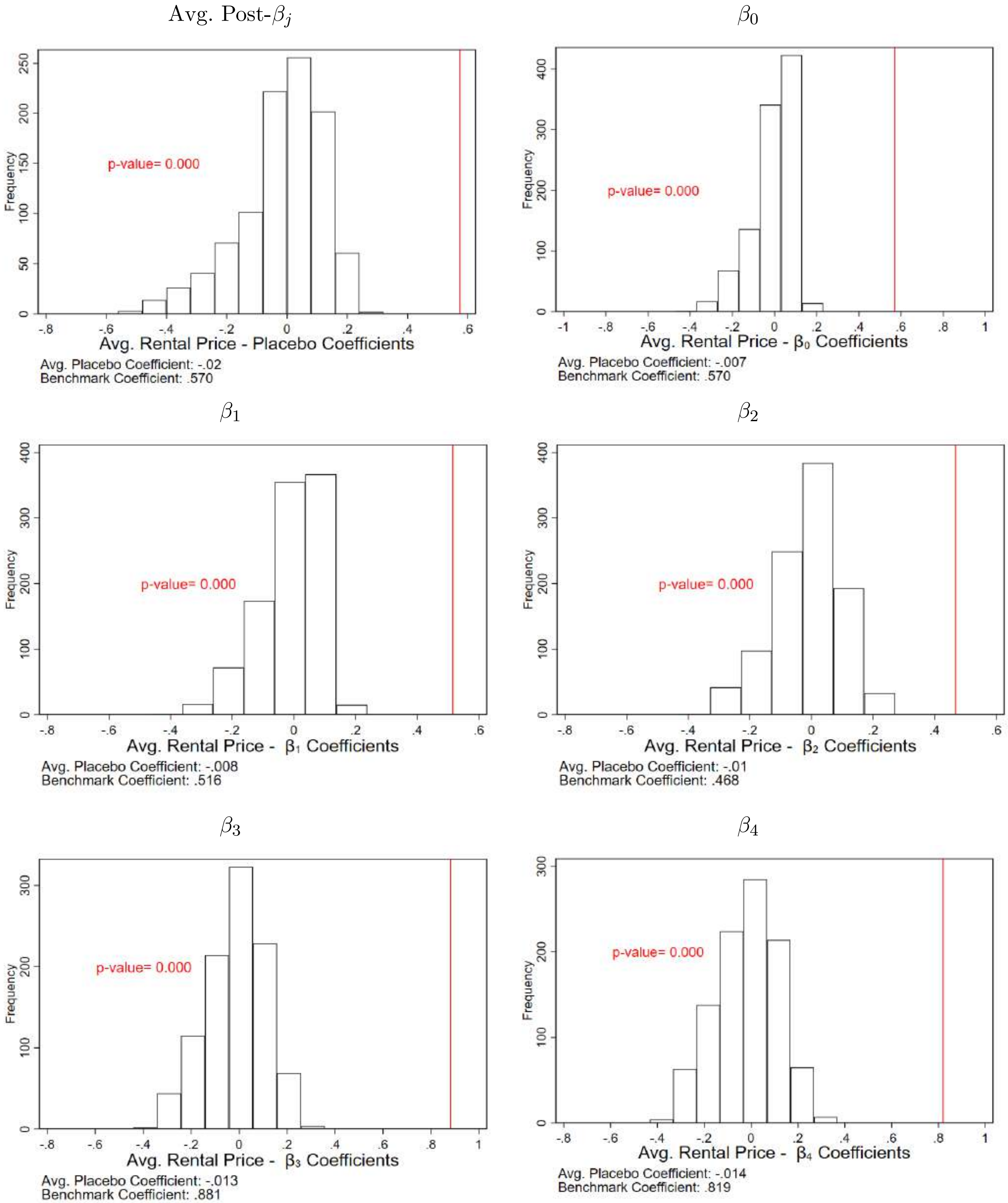
Notes: Each graph plots the distribution of 1,000 event-study placebo estimates for the Red Zone, using as a dependent variable the average rental price of residential real estate. In each panel, from the top-right to the bottom-right, figure shows the graphs relative to the post-treatment coefficients β_0, β_1, β_2, β_3, and β_4 of Equation (1), respectively. The top-left graph shows the same exercise for the average of the post-treatment β_j coefficients. Regressions control for municipality, semester-year, and residential tier fixed effects. Event-study estimates are normalized relative to semester before the bradyseismic crisis. We estimate placebo counterfactuals by randomly and fictitiously assigning the treatment to a number of municipalities equal to the size of the actual treated group—i.e., five for the Red Zone—always excluding the actually treated municipalities from the analysis. The RI p-value is calculated as the proportion of placebo coefficients that are more extreme than the observed baseline coefficient for the corresponding treatment group, shown as a red vertical line and corresponding to the estimates reported in Figure 4, left-hand graphs. The RIT p-value formula is defined in Section B.1. Below the graph on the left, we report the average placebo coefficient, and the benchmark coefficient.

Figure OA.19: RIT - Avg. Sale Price of Residential Real Estate - Emergency Zone Treatment



Notes: Each graph plots the distribution of 1,000 event-study placebo estimates for the Emergency Zone, using as a dependent variable the average sale price of residential real estate. In each panel, from the top-right to the bottom-right, figure shows the graphs relative to the post-treatment coefficients β_0, β_1, β_2, β_3, and β_4 of Equation (1), respectively. The top-left graph shows the same exercise for the average of the post-treatment β_j coefficients. Regressions control for municipality, semester-year, and residential tier fixed effects. Event-study estimates are normalized relative to semester before the bradyseismic crisis. We estimate placebo counterfactuals by randomly and fictitiously assigning the treatment to a number of municipalities equal to the size of the actual treated group—i.e., twelve for the Emergency Zone—always excluding the actually treated municipalities from the analysis. The RI p-value is calculated as the proportion of placebo coefficients that are more extreme than the observed baseline coefficient for the corresponding treatment group, shown as a red vertical line and corresponding to the estimates reported in Figure 4, left-hand graphs. The RIT p-value formula is defined in Section B.1. Below the graph on the left, we report the average placebo coefficient, and the benchmark coefficient.

Figure OA.20: RIT - Avg. Rental Price of Residential Real Estate - Emergency Zone Treatment



Notes: Each graph plots the distribution of 1,000 event-study placebo estimates for the Emergency Zone, using as a dependent variable the average rental price of residential real estate. In each panel, from the top-right to the bottom-right, figure shows the graphs relative to the post-treatment coefficients β_0, β_1, β_2, β_3, and β_4 of Equation (1), respectively. The top-left graph shows the same exercise for the average of the post-treatment β_j coefficients. Regressions control for municipality, semester-year, and residential tier fixed effects. Event-study estimates are normalized relative to semester before the bradyseismic crisis. We estimate placebo counterfactuals by randomly and fictitiously assigning the treatment to a number of municipalities equal to the size of the actual treated group—i.e., twelve for the Emergency Zone—always excluding the actually treated municipalities from the analysis. The RI p-value is calculated as the proportion of placebo coefficients that are more extreme than the observed baseline coefficient for the corresponding treatment group, shown as a red vertical line and corresponding to the estimates reported in Figure 4, left-hand graphs. The RIT p-value formula is defined in Section B.1. Below the graph on the left, we report the average placebo coefficient, and the benchmark coefficient.

C Seismic and Media Measures Data Generating Process

C.1 Earthquake Data Collection and Aggregation

The Italian National Accelerometric Network (*Rete Accelerometrica Nazionale*, RAN), managed by the Italian Department of Civil Protection, records strong ground motion generated by earthquakes. The main measure used in this work is the *Peak Ground Acceleration* (PGA), namely the maximum ground acceleration recorded at a location during an earthquake. Unlike magnitude, which describes the overall size of an earthquake, PGA measures the local intensity of ground shaking.

We collected data from the Department of Civil Protection website for the period 2020–2025, focusing only on earthquakes with magnitude of 2.5 at least.

For every earthquake, we collected the following main information: date and time, magnitude, location, depth, latitude and longitude of the epicentre, number of reporting stations, event identifier and link to the detailed record. The resulting source dataset contains 2,154 earthquake events of which only 226 events do not have epicentre coordinates.[59]

A station may report multiple measurements for the same event because of different channels or sensors. We therefore assigned to each station the maximum valid PGA among its available measurements. Events whose maximum station PGA was less than or equal to 1 cm/s^2, approximately $0.001g$, were excluded. This value is commonly reported as an approximate lower level at which ground acceleration becomes perceptible to people.[60] In total, 563 events were removed at this stage. The same strict criterion was subsequently applied to the estimated event–municipality observations.

The empirical analysis requires a measure of earthquake exposure at the municipal level. For every valid event, we therefore estimated PGA at each Italian municipality, represented by its geographic centroid. Station and municipal coordinates were projected to UTM zone 32N so that all relevant distances could be calculated in metres.

The estimation follows the general logic used in ShakeMap ground-motion interpolation. According to Joyner and Boore (1981), we start from a classic simplified ground-motion prediction equation that can be written as:

$$\text{PGA} = \exp\left(a + bM - c\ln(R + h) - dR + eS\right),$$

where M is earthquake magnitude, R is source-to-site distance, h is a near-source smoothing term, S represents site conditions, and a, b, c, d, e are empirical parameters.[61]

We now take the ratio of two PGA values: PGA_2, the estimated acceleration at the location of interest, and PGA_1, the acceleration measured at the nearest station. For two locations affected by the same

[59] These observations were excluded from the spatial estimation.

[60] See, for example: https://web.archive.org/web/20080107062111/http://www.wbdg.org/resources/seismic_design.php.

[61] The ground-motion prediction equation reported here follows the original formulation of Joyner and Boore (1981). Contemporary operational shaking and intensity estimation procedures, including those proposed by Worden *et al.* (2010), rely on extensions and refinements of the same underlying framework. For expositional simplicity, we present the original formulation.

earthquake, the common magnitude-dependent terms cancel out in the ratio:

$$\frac{\mathrm{PGA}_2}{\mathrm{PGA}_1} \approx \left(\frac{R_1 + h}{R_2 + h}\right)^c \exp[-d(R_2 - R_1)] \exp[e(S_2 - S_1)].$$

If differences in local site conditions and additional anelastic attenuation are not modelled, this becomes:

$$\frac{\mathrm{PGA}_2}{\mathrm{PGA}_1} \approx \left(\frac{R_1 + h}{R_2 + h}\right)^c.$$

When the smoothing term is also omitted, the relationship simplifies to:

$$\frac{\mathrm{PGA}_2}{\mathrm{PGA}_1} \approx \left(\frac{R_1}{R_2}\right)^c.$$

Therefore, the actual event–municipality estimates were constructed according to the following rules:

1. Each station was spatially assigned to the municipality containing its coordinates.
2. If one or more reporting stations were located inside a municipality, the PGA assigned to that municipality was the arithmetic mean of the station-level PGA values recorded inside its boundaries:

   $$\mathrm{PGA}_{m,e} = \frac{1}{N_{m,e}} \sum_{s \in m} \mathrm{PGA}_{s,e},$$

   where $N_{m,e}$ is the number of stations inside municipality m reporting earthquake e.
3. If no reporting station was located inside the municipality, the nearest station to the municipal centroid was identified using a nearest-neighbour spatial search.
4. For municipalities without an internal station, the nearest-station observation was adjusted by comparing the station–epicentre distance with the municipality-centroid–epicentre distance, as explained above. We set the attenuation exponent to $c = 1$:

   $$\widehat{\mathrm{PGA}}_{m,e} = \mathrm{PGA}_{s^*,e} \left(\frac{R_{s^*,e}}{R_{m,e}}\right),$$

   where s^* is the station nearest to the centroid of municipality m, $R_{s^*,e}$ is the distance between that station and the epicentre, and $R_{m,e}$ is the distance between the municipal centroid and the epicentre.

Thus, the station observation is reduced when the municipality is farther from the epicentre than the reference station and increased when the municipality is closer.

Finally, the event–municipality dataset was aggregated to the municipality–time level for the regions and time period considered in the baseline analyses.[62] For each municipality and period, we calculated: the number of distinct earthquake events with municipal PGA above 1 cm/s^2; the maximum PGA across those events; the minimum PGA across those events; and the average PGA across those events.

[62]Periods without an above-threshold event were assigned zero for the event count and all PGA statistics.

C.2 Media Data Collection, Classification, and Aggregation

Our collection focused on the *ANSA Regional* newswire and covers the period from July 2020 to December 2025. It includes the southern Italian mainland regions used in our baseline analyses: Abruzzo, Basilicata, Calabria, Campania, Molise, and Apulia, excluding the islands.

For the data collection, five dates were randomly selected within each week and only articles published on those dates were collected. The sampling procedure is implemented using a fixed random seed (`42`) to make the date selection reproducible.

The collected material was catalogued using the OpenAI Responses API.[63]

For ordinary articles, the headline, lead paragraph, and article text were combined and sent to the model. News-collector records were split into their constituent news items before classification. Event collectors were identified separately and were not used in the subsequent aggregations. Specifically, the workflow distinguishes three types of records:

- `collector=0`: ordinary, stand-alone news articles;
- `collector=1`: news collectors containing several separate news items, such as daily news roundups or lists of leading stories;
- `collector=2`: event collectors rather than substantive news articles.

For our purposes, we just focus on ordinary news articles (`collector=0`). The total amount of collected articles is 167,315 and when focusing on single news ones (`collector=0`) this number slightly reduces to 157,063 records.

The GPT classification was conducted in two separate rounds at different points in time. The first round performed the general article classification. The second round was conducted subsequently as a distinct search. This additional round specifically identified articles discussing Decree-Law No. 140 of 12 October 2023 and the related intervention measures for seismic and volcanic risk in the Phlegraean Fields area.

We collected 167,315 articles, among these, 10,252 are collector articles and 13,361 are non-collector articles containing no municipality information. Of the latter, 52 mention the *Campi Flegrei* but cannot be linked to a specific municipality.

Hereafter, we provide details about the two scripts.

[63] We use the `gpt-4.1-mini` model with `temperature=0`. Responses are constrained through a strict JSON schema with no additional properties. The notebooks do not set an explicit maximum output-token limit or other sampling parameters, so the corresponding API defaults apply. The system instructions require the model to rely only on explicit information in the article, avoid guessing, and return false when a boolean classification is unclear.

Script - Round 1

```
You are an information extraction system.

Analyze the provided news article and return a JSON object following the provided schema.

Rules:
- Answer only based on explicit content in the text.
- Do not infer or guess.
- If information is unclear, return false for boolean fields.
- Output must be in English.

Values of the JSON keys:
- "environmental_risk" : article related to risks associated with natural disasters (e.g.,
    bradyseism, seismic activity, volcanism)
- "real_estate" : article related to housing market, property prices, construction, real
    estate investments.
- "politics" : article related to national or regional political actors, institutions, or
    decisions.
- "local_politics" : article related to municipalities, mayors, local councils, or local
    political organizations.
- "sport_event" : article related to any mention of sports or specific sporting events.
- "municipalities" : Italian comuni explicitly mentioned and clearly named in the article.
    Do not infer from regions, provinces, or vague locations. If none are mentioned, return
    an empty list.

Sentiment classification:
- "fear" = emphasis on danger, risk, alarm
- "neutral" = factual/descriptive tone
- "reassurance" = emphasis on safety, control, or reduced risk
```

Script - Round 2

```
    You are an information extraction system.

Analyze the provided news article and return a JSON object following the provided schema.

Rules:
- Answer only based on explicit content in the text.
- Do not infer or guess.
- If information is unclear, return false for boolean fields.
- Output must be in English.

Task:
Determine whether the article explicitly discusses Decreto-Legge 12 ottobre 2023, n. 140,
    concerning urgent measures for the prevention of seismic and volcanic risk related to
    bradyseism in the Campi Flegrei area. Return true if the article clearly discusses
    measures connected to the decree, such as the "zona di intervento" or the bradyseism-
    related intervention areas.
```

Classification performance was checked against manually coded validation samples. Table OA.8 reports the accuracies.

Table OA.8: Classification Accuracy (%)

Classification	All news	News with non-empty municipalites
Panel A:		
Environmental risk	95.00	98.92
Real estate	99.50	99.46
Politics	96.50	96.77
Local politics	96.50	96.77
Sport event	99.50	99.46
Sentiment	98.50	98.39
Municipalities	96.50	96.24
Validation sample size	200	186
Panel B:		
Decree Law No. 140/2023 (Intervention Zone)	92.63	90.67
Validation sample size	95	75

Notes: This table reports classification accuracy based on Prompts 1 and 2 described above. In Panel A, accuracy is computed on a random sample of 200 individual articles drawn from the full news sample. The sentiment class aggregates the three tone-categories: neutral, fear, and reassurance. In Panel B, because the Decree Law No. 140/2023 class is rare—there were no articles labeled as 1 for this class in the randomized sample used in Panel A—the validation sample was designed to be approximately balanced between articles classified as referring to the Phlegraean Fields Intervention Zone (`decree_intervention_zone`=1) and articles classified as not referring to it (`decree_intervention_zone`=0). The validation exercise started from a sample of 100 news records, from which collector records were excluded. The resulting validation sample contains 95 stand-alone news articles, of which 75 mention at least one municipality.

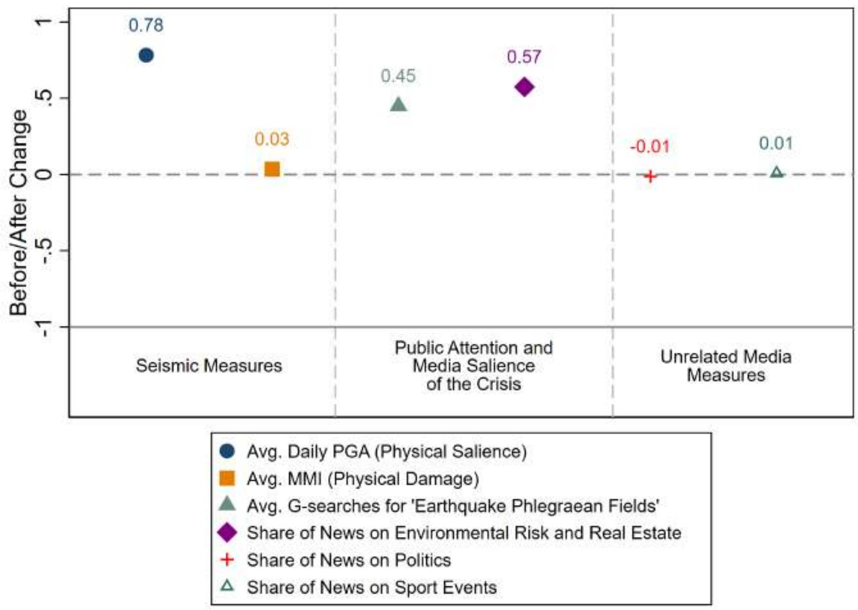
Municipality names returned by GPT are standardized and mapped to official ISTAT municipality codes. Municipality names that could not be matched directly were resolved by submitting the municipality label returned by GPT to the Google Maps Geolocation API. When the API response explicitly provided a municipality name, that name was used for the match. Otherwise, the returned geographical coordinates were assigned to a municipality through a spatial point-in-polygon match against the shapefile of Italian municipalities.

After cleaning, the municipality list is expanded so that an article mentioning multiple municipalities contributes once to each municipality it mentions. Articles without a municipality that can be mapped to an ISTAT code do not enter the municipality-period counts. Finally, article-level classifications are aggregated at the municipality-time level.

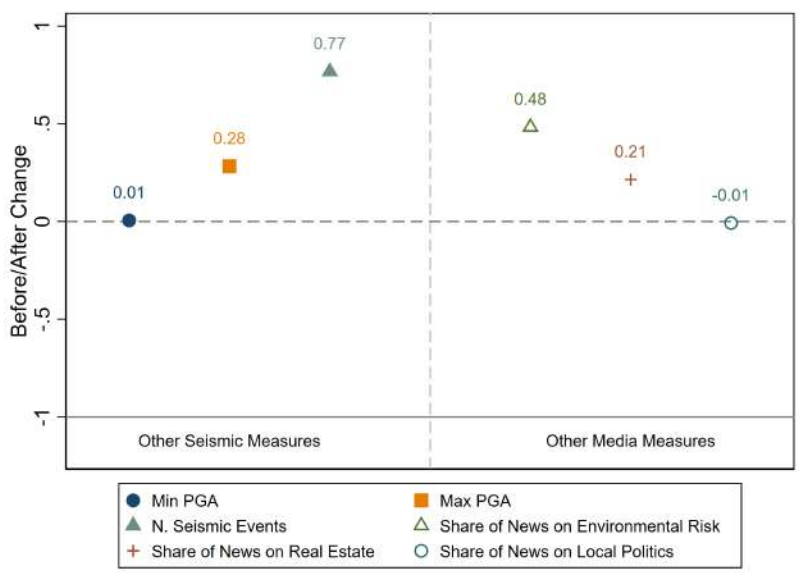
D Additional Evidence and Salience Descriptives

Figure OA.21: Phlegraean Fields - Normalized Before/After Change in Media and Seismic Measures

(a) Figure 1 measures



(b) Other measures



Notes: This figure reports before-after changes in Media and Seismic Measures for treated municipalities in the Phlegraean Fields. Before-after changes are calculated as $(X_t - X_{t-1})/(X_t + X_{t-1})$, yielding a normalized change bounded between -1 and 1. Panel (a) replicates Figure 1 with normalized changes. In panel (b), the vertical dashed line separates physical seismic measures from media-related measures. Seismic measures include minimum and maximum peak ground acceleration (PGA), as well as the number of seismic events. Media measures include the share of news articles on environmental risk, real estate, and local politics.

Figure OA.22: Example Article from the *ANSA Regional* Media Dataset

Il giorno dopo a Bagnoli, 'non ci abbandonate'

Dall'epicentro del sisma rabbia e delusione: 'non si fa niente'

NAPOLI, 13 marzo 2025, 22:50
Redazione ANSA

Italian original:

"Mi sono svegliata perché il letto ondulava. E' andata avanti così per quasi trenta secondi. E intanto si facevano le crepe nei muri. Sono scesa in strada e da allora non ho ancora il coraggio di ritornarci". La donna siede su un muretto, sotto il giubbotto indossa ancora il pigiama. Ha un sorriso stanco e la voce tremolante, con la quale prova a descrivere a chi incontra la grande paura provata stanotte da lei e dagli altri abitanti di Bagnoli, il quartiere napoletano dove la gente è scappata in strada mentre le controsoffittature delle case cadevano, gli intonaci si staccavano e sfondavano le auto in sosta. Un quartiere, Bagnoli, abituato ai terremoti, ma non alla violenza di quello che all'1:25 ha buttato giù le persone dal letto: colpa della sua accelerazione al suolo, la più forte registrata finora nella zona, e dell'energia propagata verso Est, proprio verso Napoli, piuttosto che in direzione dei Comuni flegrei di Bacoli e Pozzuoli.

Viale Campi Flegrei, corso principale di Bagnoli, stamattina è pieno di persone che si narrano a vicenda le loro notti passate in bianco in macchina, o ai giardinetti. Livio abita nel palazzo da cui sono cadute le pietre che hanno sfondato un'auto parcheggiata, una delle istantanee-simbolo di questo sisma: "abbiamo avuto tanta paura - dice - siamo usciti ed abbiamo visto le pietre cadute. Abbiamo pensato che fosse crollato qualcosa, ma poi abbiamo realizzato che a cadere in realtà era stato un lampione, che è attaccato all'edificio con dei cavi e si è tirato giù i calcinacci". Insomma, difficile di questi tempi la vita a Bagnoli, e più di qualcuno pensa di andarsene.

Una dinamica che innesca già le prime speculazioni. "So che gli affitti a Licola, al Lago Patria - spiega Livio - prima costavano 300 euro al mese, ora siamo a 700. E comunque sì, tante famiglie cominciano ad andar via".

Quella di oggi è una crisi che le persone avanti con gli anni paragonano al bradisismo degli anni '80, che portò all'evacuazione del Rione Terra: "ma le scosse erano meno violente", ricorda Amedeo, 70 anni. Con lui c'è il suo amico di sempre, Salvatore, secondo cui "la differenza è enorme, il terreno sta salendo in un modo terribile, che ci spaventa".

Paura e stanchezza per le troppe notti insonni, che aumentano di pari passo con la sfiducia, per non dire rabbia, nei confronti di chi amministra la cosa pubblica: "quello che non riusciamo a accettare - spiega Salvatore - è che dal primo bradisismo a oggi, in 50 anni, non è stata mai creata una soluzione 'vera' per Bagnoli. Le vie fuga restano a zero, le aree attrezzate a zero. All'epoca si posero sul tavolo i problemi, ma quei politici non li seppero o vollero risolvere, in particolare la questione delle strade. E così la gente di Bagnoli resta imbottigliata. Ci sentiamo abbandonati, le istituzioni ci hanno lasciato soli".

Ancora più arrabbiata è Francesca Moleti. "Ieri sera è crollato il tetto, mentre dormivo. Sono scappata in pigiama, ricoperta di polvere e mi ritrovo ancora così, nessuno mi ascolta. La verità è che il servizio per il bradisismo non c'è, diamo 800 miliardi di euro per il riarmo dell'Europa ma non abbiamo soldi per emergenze come queste. Non c'è niente, nessun supporto, nessun aiuto. È un problema del governo, non di Bagnoli, ma di tutto lo Stato. Io pago le tasse. Pago le tasse per cosa?".

Insomma, c'è paura, stanchezza e amarezza per le strade di Bagnoli, ma c'è anche chi non si perde d'animo e che all'indomani della notte più lunga apre lo stesso il suo negozio di abbigliamento, spazzando via detriti e pezzi di intonaco: "quando è arrivata la scossa - spiega Luigi - con mia moglie ci siamo abbracciati: nella stanza continuavano a cadere oggetti e noi ci siamo stretti più forte. Ci siamo sentiti soli, devo ammetterlo, nessuno durante la notte si è preoccupato per noi. Però bisogna reagire, la vita va avanti, deve andare avanti, per forza. E così stamattina, come fosse un giorno qualsiasi, abbiamo aperto il nostro negozio".

The Day After in Bagnoli: 'Do Not Abandon Us'

From the Earthquake Epicenter, Anger and Disappointment: 'Nothing Is Being Done'

NAPLES, March 13, 2025, 22:50
ANSA Editorial Staff

English translation:

"I woke up because the bed was swaying. It went on like that for almost thirty seconds. And in the meantime cracks were opening in the walls. I ran down into the street and since then I still have not had the courage to go back upstairs." The woman is sitting on a low wall; under her jacket she is still wearing her pajamas. She has a tired smile and a trembling voice with which she tries to describe to everyone she meets the great fear she and the other residents of Bagnoli felt last night, in the Naples neighborhood where people fled into the street while suspended ceilings were collapsing, plaster was coming loose, and chunks were smashing into parked cars. Bagnoli is a neighborhood accustomed to earthquakes, but not to the violence of the one that at 1:25 a.m. threw people out of bed: the reason was its ground acceleration, the strongest ever recorded so far in the area, and the way the energy propagated eastward, directly toward Naples rather than toward the Phlegraean municipalities of Bacoli and Pozzuoli.

Viale Campi Flegrei, the main street in Bagnoli, was full this morning of people telling one another about nights spent without sleep, in their cars or in the small neighborhood gardens. Livio lives in the building from which the stones fell and smashed a parked car, one of the iconic images of this earthquake: "We were terribly frightened," he says. "We went outside and saw the fallen stones. At first we thought something had collapsed, but then we realized that what had actually come down was a streetlamp, which is attached to the building by cables and pulled down chunks of plaster with it." In short, life in Bagnoli is difficult these days, and more than a few people are thinking of leaving.

It is a dynamic that is already triggering the first forms of speculation. "I know that rents in Licola and Lago Patria," Livio explains, "used to cost 300 euros a month; now they are up to 700. And yes, many families are starting to leave."

Today's crisis is one that older residents compare to the bradyseismic crisis of the 1980s, which led to the evacuation of the Rione Terra: "but the tremors were less violent," recalls Amedeo, age seventy. With him is his lifelong friend Salvatore, who says that "the difference is enormous; the ground is rising in a terrible way, and that frightens us."

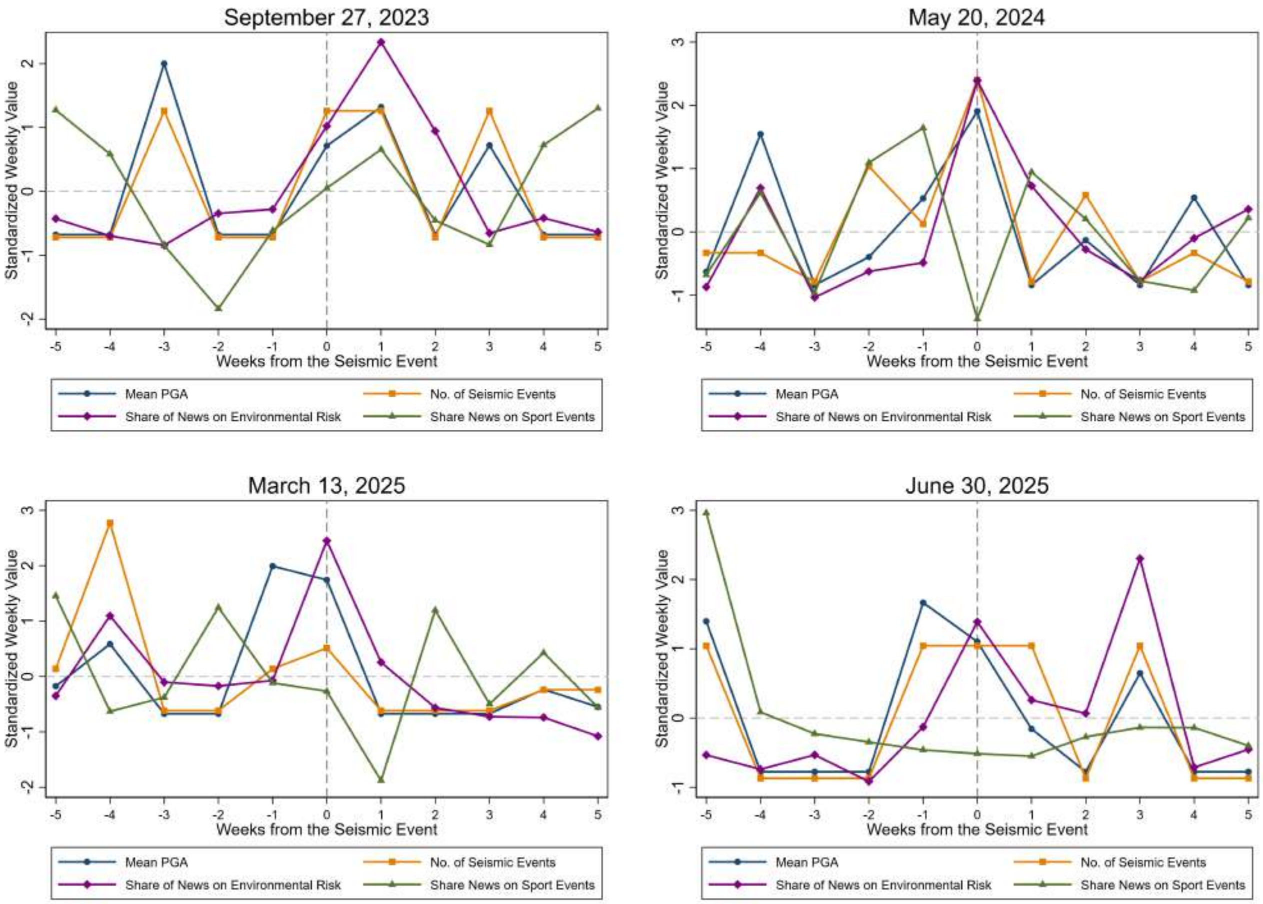
Fear and exhaustion from too many sleepless nights are growing alongside distrust, not to say anger, toward those who administer public affairs. "What we cannot accept," Salvatore explains, "is that from the first bradyseismic crisis until today, in fifty years, a real solution for Bagnoli has never been created. Escape routes are still at zero, equipped emergency areas are still at zero. Back then the problems were put on the table, but those politicians did not know how, or did not want, to solve them, especially the issue of the roads. So the people of Bagnoli remain trapped in traffic bottlenecks. We feel abandoned; the institutions have left us alone."

Even angrier is Francesca Moleti. "Last night the roof collapsed while I was sleeping. I ran out in my pajamas, covered in dust, and I am still like this now; no one is listening to me. The truth is that there is no bradyseism service. We are spending 800 billion euros on the rearmament of Europe, but we do not have money for emergencies like this. There is nothing, no support, no help. This is a problem of the government, not of Bagnoli alone, but of the entire State. I pay taxes. What do I pay taxes for?"

So there is fear, exhaustion, and bitterness in the streets of Bagnoli, but there are also people who do not lose heart and who, the morning after the longest night, open their clothing shop anyway, sweeping away debris and pieces of plaster: "When the quake hit," Luigi explains, "my wife and I hugged each other: objects kept falling in the room and we held each other more tightly. We felt alone, I have to admit it; during the night no one was concerned about us. But we have to react. Life goes on; it has to go on. And so this morning, as if it were any ordinary day, we opened our shop."

Notes: This figure reports one example article from the media dataset, shown in the original Italian and in English translation. The article documents fear, perceived institutional abandonment, housing insecurity, rent speculation, and households leaving the area. The original article is available at `https://www.ansa.it/campania/notizie/2025/03/13/il-giorno-dopo-a-bagnoli-non-ci-abbandonate_cd651e7e-db8e-4565-8d2a-7e1ea7d2ea7f.html`.

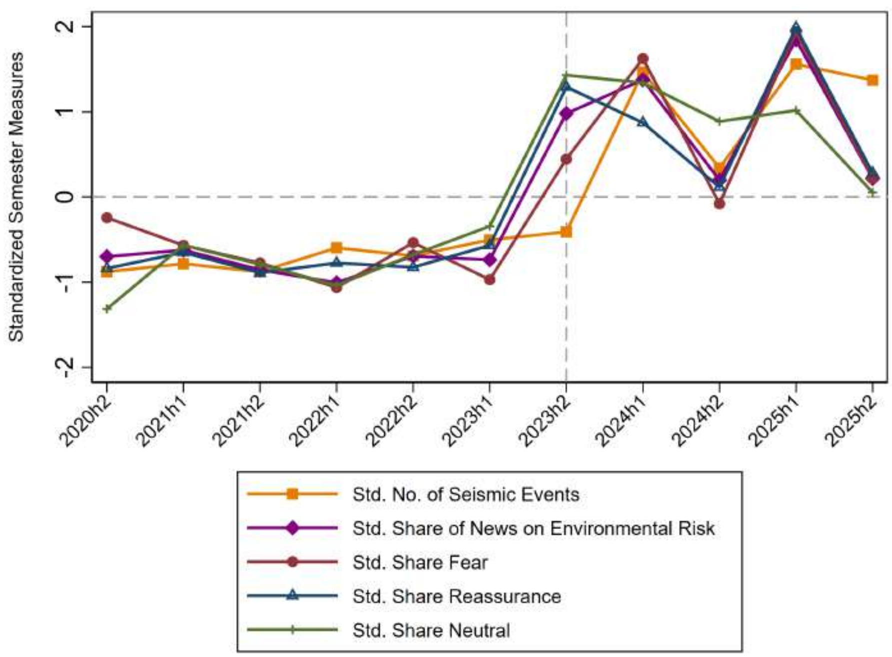
Figure OA.23: Phlegraean Fields - Seismic Events and Media Cycle



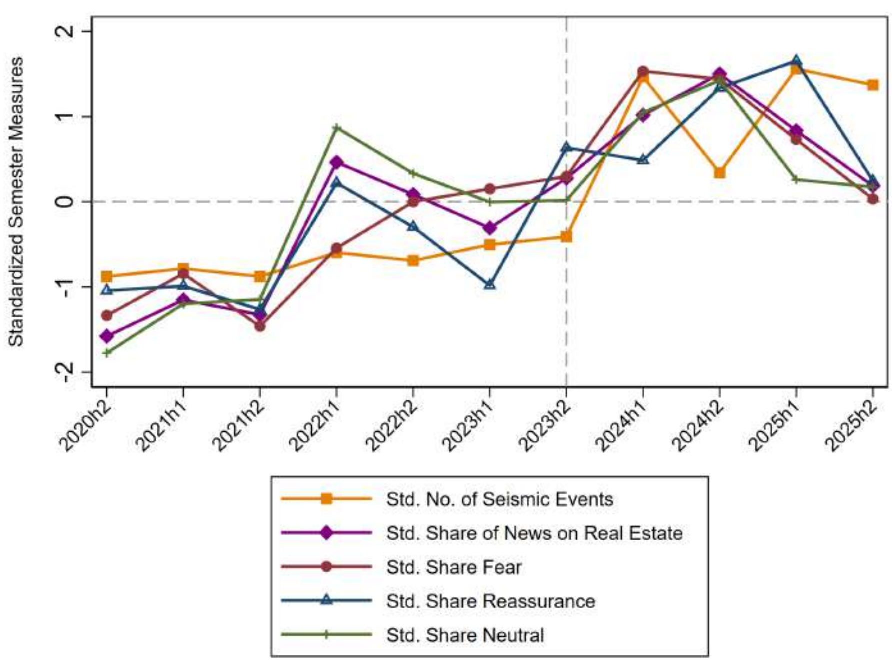
Notes: This figure reports weekly standardized values of seismic activity and media coverage around four major seismic events in the Phlegraean Fields: September 27, 2023; May 20, 2024; March 13, 2025; and June 30, 2025. The data refer only to treated municipalities in the Phlegraean Fields. In each panel, week 0 denotes the week of the seismic event, marked by the vertical dashed line. The series report mean peak ground acceleration (PGA), the number of seismic events, the share of news articles talking about environmental risk, and the share of news articles on sport events. All series are standardized within the event window, so values are expressed relative to the event-specific weekly mean and standard deviation.

Figure OA.24: Phlegraean Fields - Seismic Events and News Tone

(a) Environmental Risk



(b) Real Estate



Notes: This figure reports semester-level standardized values of seismic activity and media coverage for treated municipalities in the Phlegraean Fields. In panel (a), the series include the number of seismic events, the share of news articles talking about environmental risk, and the decomposition of that article share by tone: fear, reassurance, and neutral. In panel (b), the series include the number of seismic events, the share of news articles talking about real estate, and the decomposition of those share of articles by tone: fear, reassurance, and neutral. The vertical dashed line marks the start of the bradyseismic escalation period. All series are standardized over the sample period, so values are expressed relative to their own semester-level mean and standard deviation.

Table OA.9: Static DiD - Bradyseism And News Tone

	Share of News on Environmental Risk			Share of News on Real Estate		
	Neutral (1)	Reassurance (2)	Fear (3)	Neutral (4)	Reassurance (5)	Fear (6)
Panel A: Intervention Zone						
Treatment	0.071***	0.124***	0.153***	0.002***	0.013***	0.041***
	(0.004)	(0.012)	(0.006)	(0.001)	(0.005)	(0.007)
Observations	3,773	3,773	3,773	3,773	3,773	3,773
Avg. outcome pre-period	0.0363	0.0229	0.0701	0.0004	0.0174	0.0035
Outcome SD pre-period	0.0247	0.0281	0.0454	0.0014	0.0186	0.0052
Adjusted R^2	0.474	0.490	0.192	0.0895	0.100	0.341
Panel B: Red Zone						
Treatment	0.048***	0.093***	0.117***	0.001**	-0.001	0.030***
	(0.015)	(0.021)	(0.027)	(0.001)	(0.010)	(0.010)
Observations	3,850	3,850	3,850	3,850	3,850	3,850
Avg. outcome pre-period	0.0381	0.0197	0.0569	0.0002	0.0207	0.0051
Outcome SD pre-period	0.0242	0.0333	0.0479	0.0010	0.0287	0.0114
Adjusted R^2	0.471	0.481	0.203	0.0850	0.104	0.336
Panel C: Emergency Zone						
Treatment	0.020	0.042*	0.054*	-0.000	0.002	0.010
	(0.014)	(0.022)	(0.029)	(0.001)	(0.005)	(0.010)
Observations	4,103	4,103	4,103	4,103	4,103	4,103
Avg. outcome pre-period	0.0287	0.0107	0.0294	0.0009	0.0198	0.0042
Outcome SD pre-period	0.0401	0.0272	0.0482	0.0068	0.0394	0.0111
Adjusted R^2	0.418	0.394	0.186	0.0726	0.105	0.278
Municipality FE	YES	YES	YES	YES	YES	YES
Year-month FE	YES	YES	YES	YES	YES	YES
Residential Tier FE	YES	YES	YES	YES	YES	YES

Notes: This table reports estimates from a static version of equation (1) on a municipality-by-residential-tier panel. The outcomes are shares of news on environmental risk (columns 1-3) and shares of news on real estate (columns 4-6), overall and separately by tone: neutral, reassurance, and fear. Panels A, B, and C report results using the Intervention Zone, Red Zone, and Emergency Zone treatment definitions, respectively, as described in Section 3.1. Regressions control for municipality, year-month, and residential tier fixed effects. When the treatment is defined over the full Emergency Zone, regressions also include a Yellow Zone linear trend among the fixed effects. Standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.1.

Table OA.10: Static DiD with Salience and Decree-News Interactions - Bradyseism and Avg. Prices

	Intervention Zone		Red Zone		Emergency Zone	
	Sale Price (1)	Rental Price (2)	Sale Price (3)	Rental Price (4)	Sale Price (5)	Rental Price (6)
Total Treatment Effect	-56.29***	0.426***	-7.108	0.487***	15.80	0.489***
	(16.05)	(0.107)	(24.29)	(0.105)	(17.45)	(0.119)
Treatment	27.953**	0.497***	81.023***	0.516***	43.519***	0.282***
	(13.948)	(0.129)	(28.385)	(0.091)	(12.771)	(0.076)
Treatment interacted with:						
Physical Saliency	-11.632***	-0.008	-14.820***	-0.001	-7.139*	0.067*
	(3.144)	(0.018)	(2.995)	(0.014)	(4.152)	(0.039)
Lagged Residual Media Saliency	-8.448***	0.002	-12.070***	-0.012	-9.924***	-0.011
	(1.613)	(0.015)	(2.413)	(0.015)	(3.151)	(0.022)
Lagged Residual Share of Decree-News	-0.681	-0.034***	1.843	-0.006	2.743**	0.017
	(0.565)	(0.009)	(1.217)	(0.009)	(1.221)	(0.016)
Observations	3,420	3,359	3,490	3,429	3,720	3,659
Avg. outcome pre-period	1829.36	5.51	1667.15	5.01	1479.26	4.43
Outcome SD pre-period	325.34	0.99	333.06	0.98	481.60	1.23
Adjusted R^2	0.741	0.723	0.743	0.724	0.744	0.746
Municipality FE	YES	YES	YES	YES	YES	YES
Semester-year FE	YES	YES	YES	YES	YES	YES
Residential Tier FE	YES	YES	YES	YES	YES	YES
Saliency Scores FE	YES	YES	YES	YES	YES	YES

Notes: This table reports estimates from a static DiD specification augmented with interactions between the treatment indicator and salience measures. Columns (1)–(2) use the Intervention Zone treatment definition, columns (3)–(4) use the Red Zone treatment definition, and columns (5)–(6) use the Emergency Zone treatment definition. Within each treatment definition, the first column reports estimates for average residential real estate sale prices in levels, while the second column reports estimates for average residential real estate rental prices in levels. *Physical Saliency* is the factor score based on physical/seismic salience measures, *Lagged Residual Media Saliency* is the one-period lag of the residualized media salience factor score, and *Lagged Decree-News Saliency* is the standardized one-period lag of the residualized share of newspaper articles mentioning Decree Law 140/2023. Salience measures are standardized after factor analysis and, when applicable, after residualization. The total treatment effect is computed as a linear combination of the treatment coefficient and the three interaction coefficients, evaluated at the mean values of the salience and decree-news variables among treated observations in the estimation sample. Population-weighted regressions control for municipality, semester-year, residential tier fixed effects, and the main effects of the salience and decree-news measures. When the treatment is defined over the full Emergency Zone, regressions also include a Yellow Zone linear trend among the fixed effects. Standard errors are clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.1.

E Theoretical Appendix

E.1 Full Derivation of the Tenure and Spatial Substitution Mechanism

This appendix provides the formal details underlying the mechanism summarized in Section 6.1. A household initially attached to the exposed location E may remain in E or move to the safer location S. The benefit of moving is the reduction in perceived risk,

$$\Delta\pi_t = \pi_{Et} - \pi_{St} = s_t(h_E - h_S). \tag{10}$$

The household moves from E to S if

$$\lambda\Delta\pi_t \geq c(a), \tag{11}$$

where $\lambda > 0$ measures the utility weight placed on perceived disaster exposure. Let $m(s_t)$ be the mass of households relocating from E to S. From (11),

$$m'(s_t) > 0 \qquad \text{if} \qquad h_E > h_S. \tag{12}$$

A salience shock therefore induces spatial substitution away from the most exposed area and toward nearby markets perceived as relatively safer. If S is a residential tier perceived as safer within the Intervention Zone, the model predicts within-zone heterogeneity. If S is a nearby municipality or a nearby risk zone, the model predicts spillovers.[64]

In the short run, both ownership and rental supply are fixed in each location:

$$\bar{H}_j^B, \qquad \bar{H}_j^R, \qquad j \in \{E, S\}. \tag{13}$$

Sale prices clear the ownership market:

$$B_j(P_{jt}, R_{jt}, \pi_{jt}) = \bar{H}_j^B. \tag{14}$$

Because purchase demand falls with perceived risk, the direct effect of the salience shock is strongest in E:

$$\left|\frac{\partial B_E}{\partial s_t}\right| > \left|\frac{\partial B_S}{\partial s_t}\right| \qquad \text{when} \qquad h_E > h_S. \tag{15}$$

Thus, sale prices fall in the most exposed market when the direct perceived-risk effect dominates any inflow or rent-offset effect:

$$\frac{\partial P_{Et}}{\partial s_t} < 0. \tag{16}$$

Rental demand in the exposed location is

$$D_{Et}^R = n_E + [M_E - B_E(P_{Et}, R_{Et}, \pi_{Et})] + L_E(\pi_{Et}) - m(s_t), \tag{17}$$

where n_E is the inflow of young renters, M_E is the mass of mature households at the tenure-choice

[64] For the within-zone interpretation, let a local segment be a municipality-by-residential-tier cell $q = (m, r)$ inside the Intervention Zone. Each segment has objective exposure h_q, amenity value u_q, sale price P_{qt}, rent R_{qt}, ownership supply $\bar{H}_q^B$, rental supply $\bar{H}_q^R$, and perceived exposure $\pi_{qt} = s_t h_q$. The two-location notation above can be applied to any ordered pair of segments (q, k), where q is a more exposed sending segment and k is a receiving segment.

margin, $M_E - B_E(\cdot)$ are households delaying purchase, $L_E(\pi_{Et})$ are locally locked-in households who remain in rental housing rather than leave the area, and $m(s_t)$ are movers from E to S.

Rental demand in the receiving location is

$$D^R_{St} = n_S + [M_S - B_S(P_{St}, R_{St}, \pi_{St})] + m(s_t). \tag{18}$$

Rental-market clearing requires $D^R_{jt} = \bar{H}^R_j$. Since rental supply is fixed in the short run, rents rise wherever the increase in rental demand exceeds the direct negative effect of perceived risk on demand for that location.

In the exposed location, rents increase if tenure substitution and local lock-in dominate spatial outflows and the direct risk disamenity:

$$\underbrace{-B_{E,\pi} h_E}_{\text{delayed purchases}} + \underbrace{L'_E(\pi_{Et}) h_E}_{\text{local lock-in}} > \underbrace{m'(s_t)}_{\text{spatial outflow}} + \underbrace{\Omega_E h_E}_{\text{rental risk disamenity}}, \tag{19}$$

where $\Omega_E \geq 0$ summarizes the direct decline in rental demand due to perceived exposure. This condition is plausible in the Intervention Zone when family and work constraints are strong and the inflow of young renters continues.

In the receiving location, rents increase if inflows from E and delayed purchases in S raise rental demand:

$$\underbrace{m'(s_t)}_{\text{spatial inflow}} + \underbrace{-B_{S,\pi} h_S}_{\text{delayed purchases}} > \underbrace{\Omega_S h_S}_{\text{rental risk disamenity}}. \tag{20}$$

This condition rationalizes positive rental-price spillovers in nearby areas and heterogeneous effects across residential tiers that become relatively more attractive after the shock.[65]

E.2 Descriptive Evidence in Support of the Theoretical Assumptions

To inform the assumptions on tenure, local attachment, and insurance, we use the Bank of Italy's Survey on Household Income and Wealth (SHIW), one of the most important nationally representative household surveys in Italy. SHIW is collected biennially and provides detailed information on households' income, wealth, housing tenure, liabilities, and insurance coverage. For the years spanned by our housing-market sample, the relevant SHIW waves are 2020 and 2022. We therefore use those two waves and report weighted averages for variables observed in both waves; seismic insurance is reported from the 2022 wave, since the disaster-risk information used here is unavailable in 2020.

Table OA.11 provides descriptive evidence consistent with three assumptions underlying the mechanism. First, the SHIW data are consistent with the life-cycle ordering embedded in the tenure-choice framework. In Campania, current homeowners are older than current renters on average (59.56 versus 51.63), and the same ordering holds at the tenure-entry margin: the average age at home purchase (33.52) exceeds the average age at entry into the current rented dwelling (32.31). The smaller gap at entry than in current age suggests that the relevant adjustment margin involves households that are relatively close

[65] These inequalities imply three possible local equilibrium patterns. First, if the ownership-risk discount and rental congestion dominate spatial outflows, a segment displays the ownership–rental divergence: $\partial P_{qt}/\partial s_t < 0$ and $\partial R_{qt}/\partial s_t > 0$. Second, if spatial inflows dominate the direct risk discount, both sale and rental prices can rise in a receiving segment. Third, if spatial outflows dominate local rental congestion, both sale and rental prices can fall in a sending segment.

in the life cycle and may plausibly delay the transition from renting to owning when perceived risk rises.

Second, home purchase is predominantly local. In Campania, 93.78% of homebuyers purchase in their birth region, compared with 77.34% nationally. This pattern makes large out-of-region relocation responses less likely in the short run and supports a mechanism in which adjustment occurs primarily within Campania and nearby municipalities. Third, earthquake insurance is extremely rare in Campania: only 2.41% of households report such coverage in 2022, compared with 9.11% nationally. In a largely uninsured setting, housing wealth is more directly exposed to perceived environmental risk.

Overall, these descriptive patterns are not intended as direct evidence on treated households in the Phlegraean Fields. Rather, they support the plausibility of the model's behavioral assumptions: tenure decisions are linked to life-cycle and mobility constraints, many moves are local, and limited insurance coverage leaves housing wealth exposed to changes in perceived environmental risk.

Table OA.11: Descriptive Survey Evidence on Tenure, Mobility, and Insurance

	Campania	Italy
Mean current age of renters	51.63	54.10
	(16.92)	(16.13)
Mean age at entry into current rented dwelling	32.31	38.52
	(17.02)	(15.15)
Mean current age of homebuyers	59.56	59.13
	(16.27)	(15.42)
Mean age at home purchase	33.52	36.61
	(14.74)	(12.47)
Homebuyers purchasing in birth region (%)	93.78	77.34
	(24.15)	(41.86)
Earthquake insurance on current residence (%)	2.41	9.11
	(15.33)	(28.78)
Observations	1,498	15,880

Notes: Data are drawn from the Bank of Italy's Survey on Household Income and Wealth (SHIW). Except for seismic insurance, which is only available in the 2022 wave, entries report averages across the 2020 and 2022 SHIW waves, weighted by the number of observations in each subgroup; standard deviations are reported in parentheses. Wave-specific counts are Campania 2020: (535, 121, 200) and 2022: (963, 222, 379); Italy 2020: (6,239, 785, 3,393) and 2022: (9,641, 1,353, 5,256), where each triplet reports households, renters, and homebuyers. "Birth region" denotes the share of current-residence homebuyers who purchased in the same region in which the household reference person was born; municipality of birth is not observed in the external SHIW microdata. Seismic insurance refers to insurance against earthquake-related losses on the current residence.

F Additional Heterogeneity Analyses within the Intervention Zone

To further isolate within-tier mechanisms and reduce the confounding role of time-invariant amenities, Figure OA.25 studies heterogeneity in the post-crisis effect with respect to the pre-crisis standardized sale price level, estimated separately for (i) outskirt & suburban tiers and (ii) central & semi-central tiers according to the evidence shown in Figure 5 (right-graph).[66]

Figure OA.25 reveals substantial within-tier heterogeneity along the pre-crisis price distribution. For sale prices, panel (a), the decline in outskirt and suburban tiers is more pronounced in the premium segments of the local market. In other words, within peripheral areas of the Intervention Zone, higher pre-crisis price segments experience a stronger post-crisis contraction. Conversely, in central and semi-central tiers, the positive post-crisis effect is more pronounced in the lower-to-middle segments of the pre-crisis price distribution, while it weakens — and turns negative — in the premium segment. This asymmetric pattern is consistent with a behavioral reallocation across residential tiers. In particular, upper segments of the outskirt/suburban market are comparable in price to the lower segments of the central/semi-central market.

The stronger contraction at the top of the peripheral distribution, combined with the relative strengthening of more moderately priced central units, suggests a potential movement of demand from higher-end peripheral properties toward similarly priced but more central locations. At the same time, the negative effect observed for premium properties in central and semi-central tiers—typically targeted by higher-income households—may reflect an increase in the risk premium required by wealthier buyers in response to the crisis.

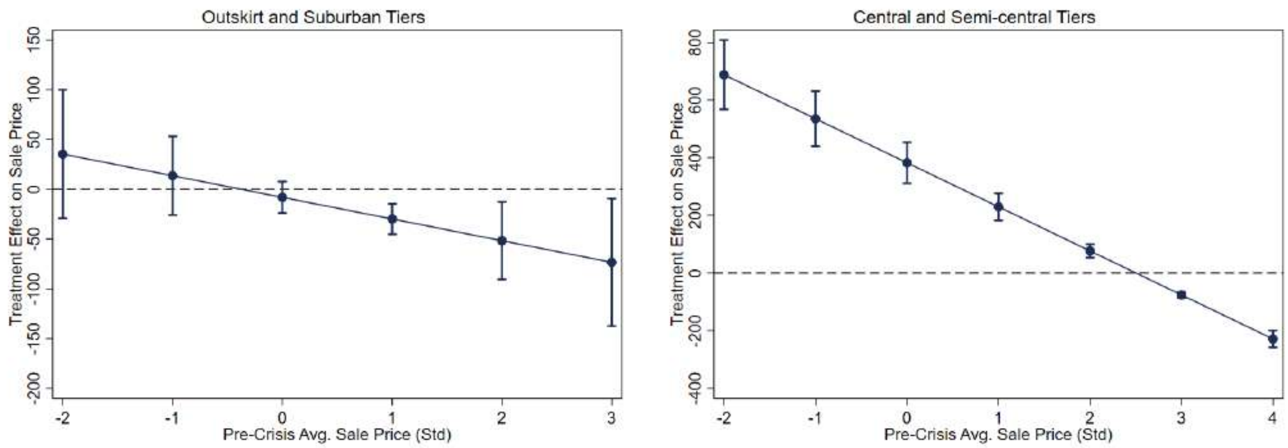
For rental prices, panel (b), the pattern further reinforces this interpretation. Within outskirt and suburban tiers, the post-crisis effect becomes more negative as pre-crisis sale prices increase, indicating that the premium segment of the peripheral rental market is disproportionately affected. By contrast, in central and semi-central areas, the rental response is increasing in the pre-crisis sale price level, implying stronger effects in the premium segment. This suggests that, in more central locations, higher-end units may attract relatively stronger rental demand, potentially reflecting a substitution of purchase decisions with renting among households incorporating updated risk perceptions.

All in all, these results point to an amplification of price dispersion across space and across segments of the housing market. The crisis appears to widen the gap between lower- and higher-priced segments within and across residential tiers, thereby increasing housing inequality in the most vulnerable areas and potentially exacerbating affordability pressures for lower-income households.

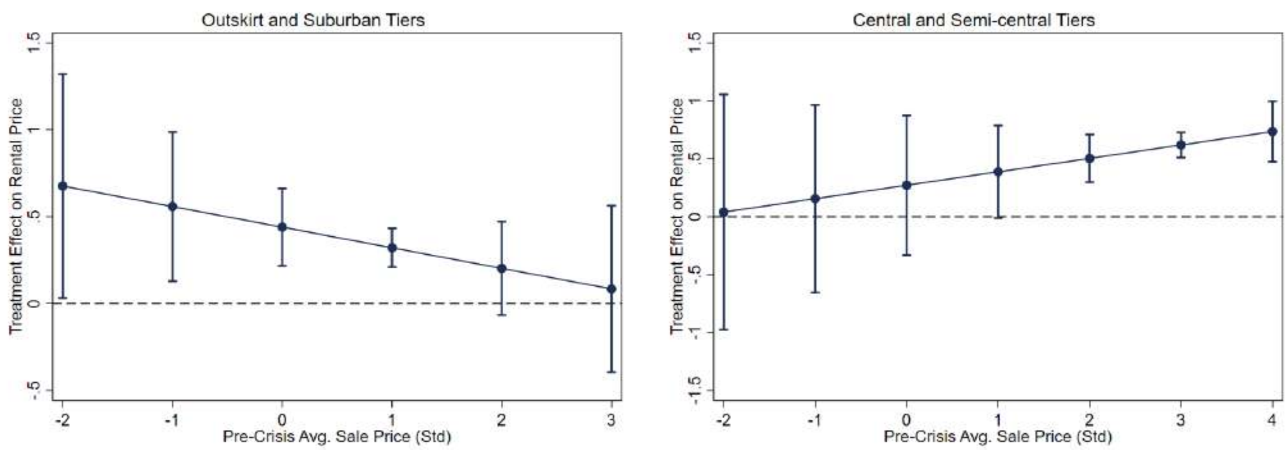
[66] With respect to Equation (9), in Figure OA.25 we estimate a specification in which the entire post-treatment period is binned into a single coefficient, and the heterogeneity interaction variable is a continuous standardized measure of the average pre-treatment sale price of residential real estate, computed at the municipality–tier level over the full pre-treatment period (H_{mf}). We then plot the estimated post-crisis effect evaluated at different values of H_{mf} (via post-estimation margins). This approach allows us to interpret the slope of the treatment effect with respect to H_{mf} as capturing differential responses across segments of the pre-crisis housing market within a given tier group (i.e., outskirt/suburban of central/semi-central).

Figure OA.25: Heterogeneous Effects by Pre-Crisis Housing Market Conditions - Intervention Zone

(a) Avg. Sale Price



(b) Avg. Rental Price



Notes: This figure reports heterogeneity in the post-crisis treatment effect within the Intervention Zone as a function of pre-crisis standardized average sale prices (H_{mf}). With respect to Equation (9), we estimate a specification in which the entire post-treatment period is binned into a single coefficient, and H_{mf} serves as the heterogeneity interaction variable, computed at the municipality–tier level over the full pre-treatment period. The graphs plot the estimated post-crisis effect evaluated at different values of H_{mf} (via post-estimation margins). Estimates are presented separately for two tier groups: (i) outskirt and suburban tiers (left-hand graphs), and (ii) central and semi-central tiers (right-hand graphs). Panel (a) considers sale prices as the outcome, while panel (b) uses average rental prices. Vertical bars report the corresponding 95% confidence intervals. The horizontal axis spans the empirical support of H_{mf} in the estimation sample, using (rounded) $\lfloor \min(H_{mf}) \rfloor$ and $\lceil \max(H_{mf}) \rceil$ as endpoints, and evaluating effects on an integer grid between these extremes.

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