



Fault Lines of Value: The Impact of Earthquake Risk on Istanbul Housing Market

Oguzhan Cepni^{1,2,3} · Ismail H. Genc⁴ · Lokman Gunduz⁵ ·
Muhammed Hasan Yılmaz^{6,7}

Received: 2 January 2025 / Accepted: 15 June 2026
© The Author(s) 2026

Abstract

Using a unique dataset of house prices and rents and a difference-in-differences methodology, we provide evidence consistent with a reassessment of earthquake-related risks in Istanbul following the Kahramanmaraş Earthquake Sequence on February 6, 2023. We find that post-earthquake increases in both house prices and rents were relatively more subdued in high-risk neighborhoods than in lower-risk neighborhoods, suggesting that seismic safety became more strongly capitalized into housing-market outcomes after the earthquake. Furthermore, houses built before the Turkish Earthquake Code of 2007 are discounted more strongly in high-risk areas relative to newer properties, highlighting the importance of building standards in shaping market responses to seismic risk. Finally, the post-earthquake premium associated with lower-risk locations is less pronounced in neighborhoods with considerably higher socio-economic status. These findings have important policy implications for earthquake-risk disclosure, building-code enforcement, and earthquake-resilience policies in Türkiye.

Keywords Earthquake Risk · Economics of Natural Disasters · Housing Market · Risk Perception · Difference-in-Differences

JEL Code D80 · Q54 · R21 · R30

Introduction

On February 6, 2023, southeastern Türkiye was struck by two devastating earthquakes, with magnitudes of 7.8 and 7.6, centered in Kahramanmaraş province. These powerful tremors impacted over 14 million people across 11 provinces, including Adana, Adıyaman, Diyarbakır, Elazığ, Gaziantep, Hatay, Kahramanmaraş, Kilis,

Extended author information available on the last page of the article

Malatya, Osmaniye, and Sanliurfa. A total of 50,783 fatalities were reported, with 115,353 people injured, making this the deadliest event in modern Türkiye's history.¹ Therefore, this catastrophic event is rightly referred to as the 'natural disaster of the century'. At least 37,984 homes were damaged or destroyed, displacing over 1.25 million people. The total cost to the Turkish economy was estimated at around USD 103.6 billion, corresponding to almost 9% of the country's 2023 GDP. The largest portion of this burden was due to damage to housing units, estimated at around USD 57 billion.²

These developments quickly reignited widespread discussion on earthquake risk across the country, as Türkiye is one of the most earthquake-prone countries, with much of its land exposed to seismic hazards as shown in Fig. 1 (Emre et al., 2018; Hussain et al., 2023).³ In particular, earthquake anxiety has once again gripped İstanbul, as residents fear facing a similar devastation. It is well documented that İstanbul lies in close proximity to the North Anatolian Fault, a major geological threat

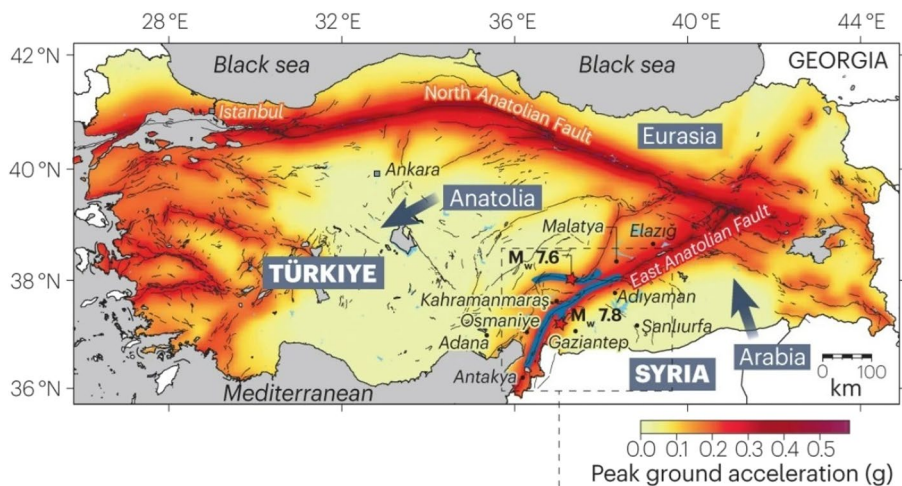


Fig. 1 Seismic Hazard Map of Türkiye and the 6 February 2023 Kahramanmaraş Earthquake Sequence. Note: This chart is sourced from Hussain et al. (2023)

¹ https://depem.afad.gov.tr/assets/pdf/Kahramanmara%C5%9F%20Depremi%20%20Raporu_02.06.2023.pdf.

² See <https://www.sbb.gov.tr/wp-content/uploads/2023/03/2023-Kahramanmaraş-and-Hatay-Earthquakes-Report.pdf> and <https://www.worldbank.org/en/news/press-release/2023/02/27/earthquake-damage-in-turkiye-estimated-to-exceed-34-billion-world-bank-disaster-assessment-report>.

³ In terms of exposure, 95% of its territory, 70% of its population and 76% of its industrial facilities are in the first- and second-degree seismic risk zones. (<https://openknowledge.worldbank.org/entities/publication/c6dc4c41-a7fb-51b0-8e31-a1efb234dae9>)

that has caused at least 34 strong earthquakes in the city over the past 2,000 years.⁴ For many residents, the extensive devastation witnessed in February 2023 heightened concerns about the inevitable yet unpredictable occurrence of a major seismic event, commonly referred to as the next “big one.” Notably, recent studies estimates a 50% probability of a major earthquake with a magnitude of 7.5 along the fault line, which could cause significant damage to İstanbul within the next three decades (Parsons et al., 2000; Şengör et al., 2005). If this prediction materializes, authorities expect around 43% of the city’s buildings to sustain varying levels of damage.⁵ The Global Facility for Disaster Reduction and Recovery also estimates that an earthquake of typical magnitude for a 200-year event striking near İstanbul has the potential to plunge 500,000 people into poverty.⁶

In this paper, we analyze how seismic risk information influences housing market dynamics in İstanbul, focusing on the aftermath of the 2023 Kahramanmaraş earthquake sequence. By treating this catastrophic event as an exogenous shock to risk perception, we examine its impact on house prices and rents across neighborhoods with varying levels of earthquake risk, despite İstanbul not being directly affected by the earthquake. Using a detailed micro-level dataset of residential property appraisals, we study price variations at the neighborhood level, combining this data with an official seismic hazard map and socioeconomic indicators to assess how risk perceptions shape housing prices. We employ a difference-in-differences methodology to quantify the relationship between seismic risk and housing market outcomes in İstanbul, leveraging the natural experiment provided by the Kahramanmaraş earthquake. Our analysis accounts for a wide range of property characteristics, including structural features and neighborhood-level risk profiles, while controlling for temporal and spatial fixed effects. Additionally, we conduct robustness checks and explore the role of rent dynamics in the post-quake period, offering a comprehensive examination of how heightened awareness of seismic risks influences housing preferences and market behavior in a highly vulnerable urban environment.⁷

⁴ The North Anatolian Fault is a right-lateral, strike-slip transform fault system that separates the Eurasian and Anatolian plates. It is widely regarded as a close analogue to the San Andreas Fault in California. Modern Türkiye has experienced a series of significant earthquakes along the North Anatolian Fault line, beginning with the 1939 Erzincan earthquake. These seismic events, occurring in a progressive east-to-west pattern and this pattern reflects the westward motion of the North Anatolian microplate, moving at a rate of 2–3 cm per year and driving the transform fault system. The northern strand of the North Anatolian Fault is the primary fault accommodating plate boundary motion, extending through the Marmara Sea, Saros Bay, and the North Aegean Trough.

⁵ <https://depremzemin.ibb.istanbul/en/wp-content/uploads/2022/08/Earthquake-Loss-Estimation-for-Istanbul-Project.pdf> and <https://data.ibb.gov.tr/en/dataset/deprem-senaryosu-analiz-sonuclari>.

⁶ World Bank. *GFDRR Annual Report 23 - Bringing Resilience to Scale (English)*. Washington, D.C. : World Bank Group. <http://documents.worldbank.org/curated/en/099836402122412500/IDU1296966181302414785188c41e3492095ce66>.

⁷ Although earthquakes are a constant concern in Türkiye, and awareness among İstanbul residents is already high, the devastating human and physical toll of the Kahramanmaraş earthquake, coupled with extensive media coverage and the widespread anxiety about an anticipated major earthquake in İstanbul, likely shifted households’ perceptions of seismic risk and their mitigation strategies. This aligns with the broader literature suggesting that information about natural hazards is often imperfect (see, e.g., Beron et al., 1997). Examining housing prices in İstanbul offers a unique opportunity to investigate whether the city’s 16 million residents revised their risk perceptions in response to this massive exogenous shock.

This paper contributes to the vast literature on the capitalization of seismic risks into housing prices (e.g., Brookshire et al., 1985; Beron et al., 1997; Naoi et al., 2009; Nakagawa et al., 2007, 2009; Hidano et al., 2015; Keskin and Watkins, 2017; Singh, 2019; Fekrazad, 2019; Shi et al., 2023). Firstly, the study expands upon existing literature by examining the impact of a major earthquake on a distant, yet also seismically vulnerable, housing market. Although they are not directly related to earthquake risk, there are prior papers evaluating the effect of distant natural hazard events on housing valuation. Ortega and Taşpınar (2018) examine the effects of hurricane Sandy on New York City, not only through the lens of affected localities, but also considering the non-damaged but flood-prone regions. Similarly, by using the residential transactions in a specific county of Florida, Fang et al. (2023) document a price premium applicable to high flood hazard zones even during a quiet hurricane period. While the existing research often focuses on the immediate aftermath of disasters within affected areas, this paper investigates how the Kahramanmaraş earthquake sequence, despite occurring nearly 1,000 km away, influenced housing prices and rents in Istanbul. This approach aligns with studies like Fekrazad (2019) but provides a unique perspective by focusing on a major earthquake's impact on a market as large and significant as Istanbul's. Furthermore, the utilization of a comprehensive micro-level dataset of official real estate appraisal reports, rather than relying on advertised prices or surveys as seen in Willis and Asgary (1997), Önder et al. (2004), and Keskin et al. (2017), allows for a more precise and granular analysis of the relationship between seismic risk and property values.

Secondly, following the methodology of Naoi et al. (2009) and Hidano et al. (2015), we adopt a difference-in-differences approach to compare pre- and post-earthquake property prices across Istanbul's diverse neighborhoods. This methodology, combined with our detailed dataset, enables a nuanced understanding of how seismic risk perceptions shifted following the Kahramanmaraş earthquakes. We further explore various mechanisms, including regulatory factors (such as the 2007 Turkish Earthquake Code), socio-economic influences, and credit conditions, providing deeper insights into the complex interplay of factors shaping housing market dynamics in the aftermath of a major seismic event. By including rent prices alongside sales prices, we broaden the scope of our analysis, offering a more comprehensive picture of the housing market's response to heightened risk awareness.

Our findings reveal significant shifts in market dynamics consistent with earlier studies, such as Singh (2019) and Shi et al. (2023), who document similar risk-related adjustments in housing markets. Neighborhoods with higher seismic risk experienced weaker price growth, while low-risk neighborhoods saw stronger increases, reflecting heightened awareness of seismic hazards. Moreover, homes built before the 2007 seismic code faced steeper discounts in high-risk areas, echoing Nakagawa et al. (2007) and Hidano et al. (2015). Notably, the study also shows that the earthquake risk premium in low-risk neighborhoods diminishes in wealthier areas, indicating that socio-economic factors play a critical role in mitigating perceived risks. Overall, by combining granular data with robust empirical methods, this paper makes a significant contribution to the literature on seismic risk capitalization and provides actionable insights for policymakers aiming to improve urban resilience and public risk awareness.

The structure of the paper is as follows: Sect. 2 provides a review of the relevant literature. Section 3 describes the novel datasets employed in this study. Section 4 details the empirical design. Section 5 presents the primary findings and supplementary analyses. Finally, Sect. 6 concludes with key remarks.

Related Previous Studies

There is a vast body of literature on the capitalization of seismic risks in housing markets, most of which examines developed markets such as those in the USA, Japan, and New Zealand located along the Circum-Pacific seismic belt—the world's most significant earthquake zone. These studies investigate how changes in earthquake risk perception, prompted by new information or tectonic events, affect house prices. Generally, they find that earthquakes, like other extreme natural events, lead to a reduction in housing prices in risky or affected areas, either because households had previously underestimated disaster risks or because of an increased perception of risk following the event.

In a seminal paper, Brookshire et al. (1985) provide early evidence that California households were aware of spatial differences in earthquake risk and had paid less for houses located in relatively hazardous areas, lending support to self-insuring behaviour consistent with the maximization of expected utility. This result is also supported by Beron et al. (1997), who show that the Loma Prieta earthquake caused a reduction in the market value of properties in earthquake zones, leading to a downward revision in hazard perception or indicating initially inflated risk perceptions. Bernknopf et al. (1990) demonstrate that the distribution of earthquake and volcano hazard notices altered risk perceptions, resulting in a decline in property values in California. Similarly, Singh (2019) highlights that average property values and rents dropped following updates to California earthquake fault maps. Fekrazad (2019) further reveals that house price indexes in high seismic risk California ZIP codes decreased in response to earthquake-related news from outside the state, compared to those in lower seismic risk areas.

Moreover, Nakagawa et al. (2007) show that rental prices in the Tokyo region generally account for local earthquake risk and the earthquake-resistant qualities of construction materials used in individual dwellings. However, they find that the discounting of earthquake risk remained unchanged even after major recent seismic events, such as the Great Hanshin-Awaji earthquake. Naoi et al. (2009) also find that both housing rents and property values in Japan were significantly and negatively correlated with regional earthquake risk in post-quake periods. However, their study also reveals that the price discount in earthquake-prone areas was significantly larger shortly after earthquake events compared to beforehand. Similarly, Hidano et al. (2015) demonstrate that residential property prices in Tokyo's low-risk zones are higher than those in high-risk areas, with variations influenced by the type of seismic hazard risk. Additionally, they find that seismic hazard risk information had minimal impact on the prices of newly constructed apartments, which were already designed to be more resistant to earthquake damage compared to older buildings. Focusing on another seismically active district, Bond and Dermisi (2017) demonstrate that house-

holds in Canterbury, New Zealand, demonstrated risk mitigation behavior through paying lower prices for the houses in the zones that were regarded to be a higher risk for future liquefaction and flooding. Huang (2021) also confirms this, showing that newly released hazard information led to a sustained decrease in property prices in neighborhoods identified as having the highest future liquefaction risk following the earthquake sequence in Christchurch, New Zealand.

Several studies have directly compared the market prices of homes in nearby or hazardous areas before and after earthquakes occurred. Among others, Murdoch et al. (1993) find a wide reduction in property values in the San Francisco Bay area after the Loma Prieta earthquake. Cheung et al. (2018) investigate to the extent to which residential property values declined in Oklahoma after experiencing potentially damaging earthquakes. Similarly, Jung & Smith, (2021) similarly highlight that residential home prices significantly declined following the 2014 South Napa and 2019 Ridgecrest earthquake sequences in California. Moreover, the effect on individual home prices was closely tied to the intensity of the earthquake experienced at each property's location. Similarly, Shi et al. (2023) find that seismic risks in Christchurch were not factored into house prices before the Canterbury earthquakes, but households readjusted their risk assessments in the post-quake period.⁸

In the case of emerging countries, many of which are located along the Alpine belt—stretching from the Mediterranean region eastward through Asia and joining the Circum-Pacific Belt in the East Indies—there are relatively few studies, mostly due to a lack of detailed data. For instance, Willis and Asgary (1997) demonstrate a significant price difference between earthquake-resistant and non-resistant houses in Tehran's housing market. Önder et al. (2004) suggest that, although the distance from fault lines and soil type were important factors in explaining house prices in İstanbul before and after the 1999 Kocaeli earthquake, none of these earthquake risk measures significantly affected the change in house values between 1995 and 2000. In a related study, examining the impact of the Van earthquake on İstanbul's housing market, Keskin et al. (2017) highlighted the spatial heterogeneity of house price changes, demonstrating that lower-priced submarkets were more negatively affected. Similarly, Deng et al. (2015) similarly find that average housing prices in Wenchuan declined as anticipated following the earthquake. They also observe a significant increase in the relative price of lower-floor units compared to higher-floor units for several months post-quake, which eventually returned to pre-earthquake levels.

Beyond seismic hazards, a broader and rapidly growing literature examines how natural-disaster risk is capitalized into real estate values more generally, offering useful points of comparison for the mechanisms we document. One strand emphasizes that capitalization is mediated by beliefs and risk perception rather than physical exposure alone. Sirmans et al. (2025) show that disaster risk commands higher capitalization rates in U.S. commercial real estate, with the effect concentrated in localities where belief in climate change is stronger—evidence that perception, not hazard

⁸A more recent line of research focuses on the impact of induced earthquakes or seismic activity due to natural gas extraction or fracturing on the local housing market, showing how housing markets are negatively affected (see, among others, Boelhouwer and van der Heijden (2018), Koster and van Ommeren (2015), Duran et al. (2023), Mothorpe and Wyman (2021), and Gibbons et al. (2021)).

alone, shapes pricing, consistent with the perception-driven repricing we identify in Istanbul. A second strand stresses that the magnitude and persistence of disaster effects depend on local institutional and socio-economic conditions. Abrokwhah et al. (2026), using a difference-in-differences design across 3,072 U.S. counties over two decades, find that disasters dampen housing-price appreciation but that the decline is smaller and shorter-lived where economic freedom is greater, paralleling our finding that the post-quake risk premium is muted in higher-status neighborhoods. The pricing of forward-looking and chronic risk is examined by Lee and Zheng (2026), who find that anticipated high-tide flooding from sea-level rise depresses coastal home prices and, relevant to our joint treatment of sales and rents, depresses rents roughly threefold, reflecting expectations of future adaptation. Finally, work on spatial spillovers shows that disaster risk is repriced even for physically undamaged assets: Fang et al. (2026) document that office properties near Hurricane Sandy–damaged sites experienced persistent price declines of 8 to 15%, a contagion mechanism analogous to the reassessment we observe in an Istanbul market that was itself untouched by the Kahramanmaraş sequence.

Data

In this study, our principal dataset of price formation in housing sector is sourced from the Central Bank of the Republic of Türkiye (CBRT). In particular, we utilize transaction-level data based on valuation reports for individual residential houses. These reports are prepared by real estate appraisal companies and demanded by commercial banks as an input for the allocation process of mortgage credits.⁹ In fact, CBRT uses the repository of this data to construct and publicly disseminate the Residential Property Price Index at the regional level (NUTS-2) to monitor the price formation in the Turkish housing market (Fig. 2).¹⁰ Thus, we cover the entire universe of quoted prices for mortgaged houses as well as observing a vastly detailed information on their locations and a broader set of house characteristics.

We follow certain steps to form our sample for empirical analysis. We drop observations with missing price and location information (provinces, districts and neighborhoods in order of decreasing geographical hierarchy, which are *iller*, *ilçeler* and *mahalleler* in Turkish, respectively). Then, we only maintain the houses located in İstanbul according to province (NUTS-3) classification. We determine the sample period as such it spans the interval between January 2022 and February 2024. In the following step, we gather information on the proneness to earthquake damage at the neighborhood-level from the earthquake risk map used by the Turkish Catastrophe

⁹ Although appraisal-based values may not perfectly mirror transaction prices, they are prepared by licensed companies following standardized procedures and are directly used by commercial banks in mortgage decisions, lending them institutional credibility and broad market coverage.

¹⁰ More details on CBRT Residential Property Price Index can be found here: <https://www.tcmb.gov.tr/wps/wcm/connect/EN/TCMB+EN/Main+Menu/Statistics/Real+Sector+Statistics/Residential+Property+Price+Index/>.

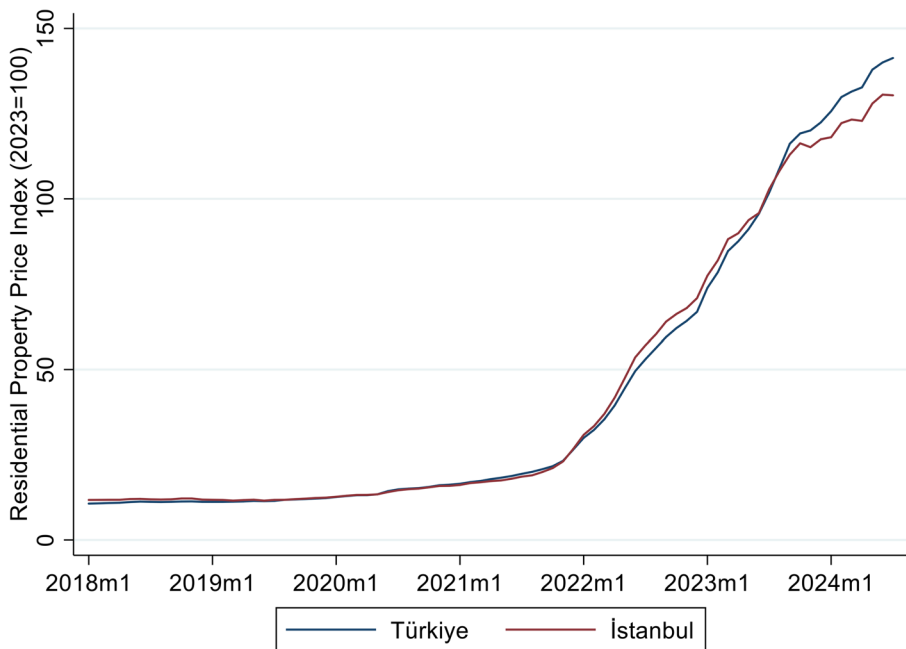


Fig. 2 Residential Property Price Index. Note: This chart shows the evolution of macro-level Residential Property Price Index prepared by CBRT for the period 2018–2024. The data is sourced from Electronic Data Dissemination System (EVDS) of CBRT. The blue solid line represents the overall index for Türkiye, whereas the solid red line stands for the index of İstanbul. The values of the indicator are normalized to the level of 100 based on the year 2023

Insurance Pool (TCIP).¹¹ This detailed map categorizes each neighborhood in the İstanbul province based on the severity of earthquake risk via discrete scores ranging from 1 to 5. In this ranking, the score of 1 refers to the highest risk group, while 5 refers to the lowest (Fig. 3).

We merge the earthquake risk scores with housing appraisal data by using district-neighborhood pair names. In order to improve the reliability of the merging process, we manually correct irregularities in the district and neighborhood names available in the appraisal data including but not limited to typos in neighborhood names, missing neighborhood names, street names recorded instead of neighborhood names, neighborhood names assigned to incorrect district names, and other related issues. To do these corrections, we use neighborhood names recorded in the land register for each houses (again available in the CBRT micro data) and Google Maps searches, whichever is applicable. Our final sample is comprised of 139,913 house appraisals from 836 neighborhoods in 39 İstanbul-based districts.

¹¹ The TCIP is a public legal entity providing mandatory earthquake insurance for privately owned residential properties built on registered land in compliance with legal requirements. It was established in 2000 after the Kocaeli earthquake of 1999. Premiums vary with the location (seismic risk zone) and building type. Covered risks include the material losses in the buildings caused by the earthquakes.

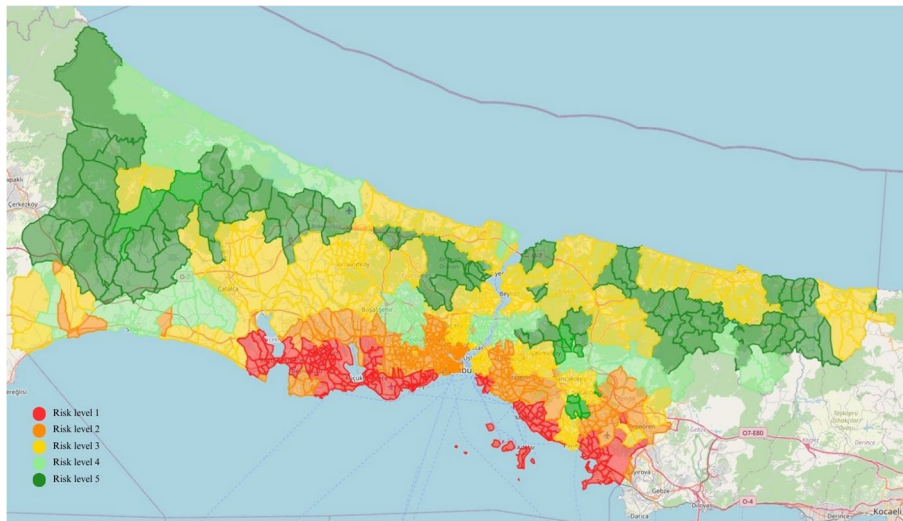


Fig. 3 Seismic Risk Map for İstanbul. Note: This graph displays the seismic risk levels, ranging from the highest (risk level 1) to the lowest (risk level 5), as determined by the Turkish Catastrophe Insurance Pool

Methodology

To test the relationship between earthquake-related risks and house prices, our empirical strategy involves a difference-in-differences model. Our specification is determined by the timing of the Kahramanmaraş earthquake (treated as a plausibly exogenous variation in economic agents' awareness of the costs of natural disasters) and the distribution of neighborhood-level exposure to earthquake risks in İstanbul. In the baseline case, we estimate the following model using OLS:

$$\begin{aligned} \ln(\text{House Price})_{i,t,d,n} = & \alpha + \beta_1 * \text{Post}_t \\ & + \beta_2 * \text{Earthquake Risk}_{d,n} \\ & + \beta_3 * \text{Post}_t * \text{Earthquake Risk}_{d,n} \\ & + \gamma X_{i,t,d,n} + \mu_t + \pi_d + \epsilon_{i,t,d,n} \end{aligned} \quad (1)$$

where $\ln(\text{House Price})_{i,t,d,n}$ refers to the natural logarithm of the price (per square meter) quoted for house i at time t located in district d neighborhood n . The dichotomous variable Post_t marks the occurrence of the Kahramanmaraş earthquake by taking the value of one after February 2023, and zero otherwise¹². $\text{Earthquake Risk}_{d,n}$

¹² In our study, the variable “Post” is defined based on the date of appraisal. In Türkiye, the house transaction process mirrors that in the U.S. but is typically faster: the transaction price is set when a listing becomes pending, followed by the buyer's mortgage application. If the buyer is creditworthy (a swift assessment), the bank awaits the appraisal report (usually 3–5 days), then finalizes the loan and transfers funds (e.g., up to 75% of appraised value) on the same day, making appraisal and closing dates generally identical. Our dataset includes not only mortgaged properties but also those appraised during loan processes that did not result in mortgage-financed sales, offering a broader market view influenced by conditions irrespective of final financing.

represents the geographical distribution of earthquake risk within Istanbul using the TCIP risk map score assigned to district d neighborhood n . Higher values of this score correspond to lower expected earthquake damage. The main coefficient of interest is the interaction term ($Post * Earthquake Risk$), which measures the differential post-earthquake change in house prices associated with TCIP-measured seismic safety. The TCIP score captures neighborhood-level variation in relative seismic safety, and the interaction with the post-earthquake indicator captures how this variation became differentially capitalized into prices after the Kahramanmaraş earthquake affecting a vast area in Eastern Türkiye that took place on February 2023. Therefore, our main coefficient of interest, $Post \times Earthquake Risk$, should be interpreted as the post-Kahramanmaraş change in the relative price premium associated with TCIP-measured seismic safety. It does not represent the pure structural effect of physical earthquake risk in isolation. Instead, it captures whether prices in safer neighborhoods increased more than prices in riskier neighborhoods after the earthquake, conditional on observed housing characteristics, time effects, and spatial fixed effects.¹³

Thanks to the rich set of observable house characteristics, we extend the specification in Eq. (1) with a myriad of house controls (X). These controls are the number of rooms (Rooms), the availability of elevators (Elevator), the availability of a pool (Pool), the availability of carpark (Carpark), the availability of security staff (Security), heating style (Heating), the number of washrooms (Washroom), the number of kitchens (Kitchen) and the difference between the current year and the construction year of the house (House Age).

We incorporate month fixed effects (μ_t) to account for time-varying and seasonal forces, while district fixed effects (π_d) are included to account for unobserved heterogeneity across districts. ϵ stands for the stochastic error term.¹⁴ We winsorize continuous variables at 1st and 99th percentiles to minimize the impact of outliers. We utilize robust standard errors clustered at the neighborhood level, as our treatment of interest, earthquake risk, varies at this observation level. Variable definitions and data sources are provided in Table 1. Summary statistics are given in Table 7 of the Appendix.

¹³ The identifying assumption is that, absent the Kahramanmaraş earthquake and the associated increase in earthquake-risk salience, neighborhoods with different TCIP earthquake-risk scores would have followed comparable price trends after conditioning on the included controls. This is a conditional parallel-trends assumption. Because our setting is observational, we cannot fully rule out the possibility that unobserved time-varying neighborhood factors correlated with earthquake-risk scores also affected house prices during the sample period. For this reason, the estimates should be interpreted as evidence of differential post-earthquake capitalization of seismic safety, rather than as an unconditional causal effect of earthquake risk alone.

¹⁴ We acknowledge that the two-year sample window represents an unavoidable limitation, as month fixed effects may not fully account for all within-period developments beyond seasonality, despite additional controls that are considered in the subsequent robustness checks.

Table 1 Variable Definitions

Variable	Definition	Data Source
ln(House Price)	The natural logarithm of house price (per square meter)	CBRT
Post	A binary variable taking the value of one after February 2023, otherwise zero	-
Earthquake Risk	A continuous variable taking the values ranging from 1 to 5 based on the earthquake risk exposure of individual neighborhood (1 refers to highest risk, 5 refers to lowest risk)	TCIP Risk Map
Rooms	The number of rooms	CBRT
Elevator	A binary variable taking the value of one if house premises have an elevator, otherwise zero	CBRT
Pool	A binary variable taking the value of one if house premises have a pool area, otherwise zero	CBRT
Carpark	A binary variable taking the value of one if house premises have a carpark, otherwise zero	CBRT
Security	A binary variable taking the value of one if house premises have security staff, otherwise zero	CBRT
Heating	A categorical variable describing the heating system of house	CBRT
Washroom	The number of washrooms	CBRT
Kitchen	The number of kitchens	CBRT
House Age	The difference between current year and construction year of house	CBRT
Social	A binary variable taking the value of one if house is located in a neighborhood with socio-economic status grade of A+, A, B+, B, otherwise zero	İstanbul Metropolitan Municipality
Credit	The ratio of loan amount to total house value	CBRT
Construction 2007	A binary variable taking the value of one if house is constructed after the year 2007, otherwise zero	CBRT
Binary Earthquake Risk	A binary variable taking the value of one if house is located in a neighborhood with Earthquake Risk score of 1 or 2, otherwise zero	TCIP Risk Map
ln(Real House Price)	The natural logarithm of house price that are deflated with İstanbul TurkStat CPI index or İstanbul Trade Union (İTO) White Goods price index	CBRT, TurkStat, İTO
Mortgaged Sales Ratio	The ratio of mortgaged sales to total house sales (at district-level)	TurkStat
Mortgage Interest Rate	The weighted-average rate applicable to mortgage loans (at industry-level)	CBRT
Population Growth Rate	The growth rate of total population (from 2023 to 2024) (at district-level)	TurkStat

This table provides the mnemonics, definitions and data sources for the variables used in the main and extended estimations. Our overall sample spans the interval between January 2022 and February 2024. In detail, the sample is composed of observations belonging to 139,913 unique house appraisals from 836 neighborhoods of 39 districts in İstanbul. Earthquake Risk variable is sourced from <https://dask.gov.tr/tr/interaktif-deprem-haritasi>

Results

In this section we provide empirical results for the model discussed above. Our baseline specification tries to discover the relationship between the earthquake risk and

house prices in İstanbul in the aftermath of the devastating Kahramanmaraş earthquake sequence. It is quite conceivable that the attention to natural hazards in Türkiye has been heightened because of the recent experience in the country. We also report extended analysis including several robustness checks and test the applicability of the parallel trends assumption in our design. Furthermore, this section entails the presentation of additional analysis, which tackles the issue of how rent prices are influenced by earthquake risk and explores potential heterogeneities of treatment effect contingent on certain economic, financial and regulatory channels.

Baseline Findings

The main results are given in Table 2, which analyzes how the relationship between the earthquake risk and house prices in İstanbul evolved following the overall change in perceptions due to the disaster of Kahramanmaraş earthquake. In column (1), we consider the most parsimonious specification. Column (2) adds the vector of house characteristics, column (3) augments month fixed effects,¹⁵ while column (4) is the most saturated model by also controlling for district fixed effects. In all columns, we obtain a positive and significant coefficient attached to *Post * Earthquake Risk* term. The coefficient in the most comprehensive model (Column 4) is 0.0231. This coefficient measures the differential post-earthquake change in house prices associated with TCIP-measured seismic safety. Since higher Earthquake Risk scores correspond to safer neighborhoods, the estimate suggests that a one-unit increase in the TCIP score is associated with approximately 2.31% stronger post-earthquake house price growth. Note, since higher Earthquake Risk scores mean safer areas, this is

Table 2 Baseline Estimations

	(1) ln(House Price)	(2) ln(House Price)	(3) ln(House Price)	(4) ln(House Price)
Post x Earth- quake Risk	0.0238*** (0.0069)	0.0232*** (0.0066)	0.0236*** (0.0066)	0.0231*** (0.0054)
Post	0.6139*** (0.0171)	0.6008*** (0.0162)	0.6469*** (0.0161)	0.6609*** (0.0126)
Earthquake Risk	0.0295 (0.0198)	0.0250 (0.0158)	0.0280* (0.0159)	0.0066 (0.0147)
# of observations	139,913	139,913	139,913	139,913
House Controls	No	Yes	Yes	Yes
Month FE	No	No	Yes	Yes
District FE	No	No	No	Yes
Adj. R ²	0.261	0.455	0.527	0.725

¹⁵ Our findings for the impact on house prices remain similar when time fixed effects are employed instead of month fixed effects.

in addition to the baseline price difference between safer and riskier areas. In other words, the earthquake amplified the premium placed on safer neighborhoods.¹⁶

This consistent finding implies that the pricing behavior in the İstanbul housing market has reflected an additional premium such that neighborhoods inherently less prone to earthquake damage (having larger values of the Earthquake Risk indicator) have experienced a stronger rise in house prices following the change in sentiment due to the Kahramanmaraş earthquake, relative to counterpart neighborhoods that are categorized as high-risk areas (having smaller values of the Earthquake Risk indicator). This finding suggests that the heightened awareness among buyers, leading to a stronger preference for properties in safer areas following the earthquake. Importantly, this finding holds even when controlling for housing characteristics, time trends, and district-level differences.

Furthermore, to gain more detailed insights on potential non-linear relationship, we repeat the estimations by adopting a specification including separated Earthquake Risk variables, which correspond to standalone dummy variables for each risk levels (Table 8 of the Appendix). Compared to the base level defined by the Earthquake Risk score of 1, the houses from safer localities display incrementally higher premium concerning the price changes before-after Kahramanmaraş earthquake, except for the last risk group.¹⁷

Robustness Checks

In this sub-section, we perform a battery of robustness tests for our baseline results. For the sake of brevity, we demonstrate the findings pertaining to the main coefficient of interest ($Post * Earthquake Risk$) in Table 3 together with the auxiliary infor-

¹⁶ The insignificant coefficient on the static earthquake risk variable in most cases is understandable in light of several factors. First, this coefficient reflects long-run price differences between high- and low-risk areas that may have already been largely capitalized into property values over decades. Additionally, risk-perception inertia can cause homebuyers to underweight (or even ignore) known earthquake risk in the absence of recent shocks. In İstanbul's context, despite the geophysical prominence of earthquake risk, many households may have treated catastrophic quakes as abstract or low-probability events before experiencing one, implying only a modest or statistically insignificant cross-sectional risk discount prior to a salient realization. This interpretation is consistent with evidence from the broader literature. For example, Naoi et al. (2009) document that the price discount for homes in high-risk areas became significantly larger after a major earthquake than before, suggesting that households tend to underestimate earthquake risk when there has not been a recent occurrence. Similarly, Shi and Naylor (2023) find that seismic risk was essentially not priced prior to the 2010–11 Canterbury earthquakes, but after the quake, houses in riskier neighborhoods sold at a greater discount, indicating belief updating in the post-quake period. Related evidence from Türkiye also points to an attention/salience channel: Abbasoğlu and Kalkan (2025) document muted housing price responses to probabilistic information shocks (the 2018 national hazard-map revision), but substantially stronger adjustments following the realized February 2023 earthquakes. Taken together, these findings emphasize that when risk information is not salient, the observed price penalty for risk can be modest or statistically insignificant, but it can emerge sharply once a disaster (or a vivid information shock) makes the risk salient. In our setting, this mechanism implies that pre-earthquake risk differentials may appear muted in levels, while the post-earthquake dynamics capture a swift revaluation once earthquake risk becomes more salient.

¹⁷ This specific analysis and the baseline estimation remain statistically and economically same when the observations belonging to the safest group (with earthquake risk score of 5) are discarded due to the limited number of observations.

Table 3 Robustness Checks

	(1) [-6+6] months estimation interval	(2) [-9+9] months estimation interval	(3) Only fully constructed houses	(4) Discarding earthquake score of 3
Post x Earthquake Risk	0.0094** (0.0046)	0.0172*** (0.0045)	0.0225*** (0.0055)	0.0208*** (0.0063)
Post	0.5597*** (0.0148)	0.5548*** (0.0114)	0.6589*** (0.0127)	0.6617*** (0.0129)
Earthquake Risk	0.0108 (0.0145)	0.0065 (0.0142)	0.0075 (0.0148)	0.0189 (0.0189)
# of observations	70,211	101,175	134,382	108,184
House Controls	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Adj. R ²	0.701	0.737	0.725	0.732
	(5) Discarding earthquake score of 2,3,4	(6) Additional house controls	(7) Non-win-sorized data	(8) Month-by-district FE
Post x Earthquake Risk	0.0155*** (0.0056)	0.0220*** (0.0055)	0.0231*** (0.0054)	0.0244*** (0.0055)
Post	0.6643*** (0.0126)	0.6663*** (0.0128)	0.6611*** (0.0127)	0.6586*** (0.0126)
Earthquake Risk		0.0090 (0.0147)	0.0065 (0.0149)	0.0061 (0.0146)
# of observations	43,887	139,762	139,913	139,913
House Controls	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	No
District FE	Yes	Yes	Yes	No
Month x District FE	No	No	No	Yes
Adj. R ²	0.759	0.733	0.719	0.727
	(9) Time and neighborhood FE	(10) Using only European side neighborhoods	(11) Using only Asian side neighborhoods	(12) Binary earthquake risk variable
Post x Earthquake Risk	0.0178*** (0.0051)	0.0199** (0.0086)	0.0283*** (0.0066)	0.0484*** (0.0107)
Post		0.6634*** (0.0169)	0.6516*** (0.0199)	0.6943*** (0.0065)
Earthquake Risk	0.0503** (0.0208)	0.0515*** (0.0179)	-0.0483*** (0.0182)	0.0475 (0.0323)
# of observations	139,868	56,479	56,479	139,913
House Controls	Yes	Yes	Yes	Yes
Month FE	No	Yes	Yes	Yes
District FE	No	Yes	Yes	Yes
Time FE	Yes	No	No	No
Neighborhood FE	Yes	No	No	No
Adj. R ²	0.802	0.732	0.712	0.726
	(13) Using real house prices (Istanbul CPI)	(14) Using real house prices (Istanbul Trade Union index)	(15) Excluding house controls of Pool, Kitchen and Security	(16) Controlling for district-level mortgaged sales ratio
Post x Earthquake Risk	0.0247*** (0.0054)	0.0231*** (0.0052)	0.0242*** (0.0055)	0.0239*** (0.0066)

Table 3 (continued)

	(1) [-6+6] months estimation interval	(2) [-9+9] months estimation interval	(3) Only fully constructed houses	(4) Discarding earthquake score of 3
Post	0.2023*** (0.0127)	0.0961*** (0.0123)	0.6649*** (0.0126)	0.6471*** (0.0160)
Earthquake Risk	0.0061 (0.0145)	0.0066 (0.0145)	0.0077 (0.0155)	0.0398** (0.0165)
# of observations	139,913	139,913	139,913	139,913
House Controls	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	No
Adj. R2	0.656	0.654	0.681	0.533
	(17) Controlling for aggregated mortgage interest rates	(18) Controlling for district-level population growth rate		
Post x Earthquake Risk	0.0238*** (0.0055)	0.0275*** (0.0061)		
Post	0.6332*** (0.0132)	0.6436*** (0.0147)		
Earthquake Risk	0.0064 (0.0147)	0.0502*** (0.0126)		
# of observations	139,913	139,913		
House Controls	Yes	Yes		
Month FE	Yes	Yes		
District FE	Yes	No		
Adj. R2	0.726	0.607		

This table provides the robustness checks for the main regression estimations as given in column (4) of Table 2. In columns (1) and (2), we narrow down the estimation interval 6 and 9 months around the occurrence of Kahramanmaraş earthquake, respectively. In column (3), we include the fully constructed houses in the sample. In column (4), we discard the observations corresponding to earthquake risk score of 3 based on TCIP risk map. In column (5), we discard the observations corresponding to earthquake risk scores of 2, 3, 4 based on TCIP risk map. In column (6), we extend the set of house controls by including the variables related to number of floors, energy efficiency, construction quality and construction style. In column (7), we use raw data (of continuous variables) instead of winsorized versions. In column (8), we replace month fixed effects with higher order month-by-district fixed effects. In row (9), we integrate time (month-by-year) and neighborhood fixed effects separately into the model. In column (10), we limit the sample coverage located to European-side neighborhoods. In column (11), we only use the houses located in Asian-side neighborhoods. In column (12), we utilize as the treatment variable. Instead of nominal house prices, columns (13) and (14) employ real house prices that are deflated with İstanbul TurkStat CPI index and İstanbul Trade Union (İTO) White Goods price index, respectively. In column (15), exclude the control variables and . In column (16), we use the district-level control variable of the mortgaged sales to total house sales ratio. In column (17), we control for sector-level monthly weighted-average interest rate on housing loans. In column (18), we use the district-level control variable for the population growth rate in the post-earthquake episode. Variable definitions and data sources are given in Table 1, whereas summary statistics are given in Table 7 of the Appendix. Standard errors clustered at neighborhood level are shown in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10%, respectively

mation and diagnostics on regressions. The following set of robustness checks are all based on the modified versions of the full specification presented in Eq. (1), which is shown in column (4) of Table 2.

In order to investigate whether the earthquake premium in house prices persists across different event periods, we shorten the estimation window. Specifically, in column (1), we limit the estimation to six months before and after the Kahramanmaraş earthquake, whilst we focus on nine months before/after the timing of the same earth-

quake in column (2). In both cases, our analysis continues to point out to a significant difference in price changes between houses located in low and high-risk regions of İstanbul, indicating that the main finding is not sensitive to the specific event window chosen. In column (3), we restrict the sample coverage by only considering fully constructed houses. In our sample, this condition corresponds to 134,382 houses (out of the original sample of 139,913). We still observe a positive and significant impact on house prices in low-risk neighborhoods, suggesting that the relationship between earthquake risk and house prices holds for completed properties.

Our empirical design utilizes the TCIP earthquake map, which rates the neighborhoods with scores of 1, 2, 3, 4, and 5 to quantify the potential earthquake damage. In column (4), we discard all the observations located in neighborhoods with an earthquake risk score of 3, essentially removing the “middle ground” risk category. In column (5), we further refine this by discarding neighborhoods with the scores of 2, 3, and 4, leaving only the most extreme categories (1 and 5). The motivation behind this robustness check is to clearly delineate between low and high-risk localities. Even with these stricter definitions, the coefficient of interaction term remains positive and statistically significant in both tests. This reinforces our confidence that the observed effect is not simply an artifact of how we categorize risk but a genuine reflection of market behavior. In column (6), we enhance the list of control variables by directly including additional house characteristics such as the number of floors, energy efficiency, construction quality and construction style. This addresses the possibility that our initial set of controls might have missed some important factors influencing house prices. In column (7), instead of winsorized versions, we employ raw data (of continuous variables) to perform OLS estimations. The positive and significant coefficient on interaction term persists even when using raw data, suggesting that our results are not an artifact of the winsorization process.

Furthermore, we revise the modelling approach by including higher-order fixed effects. In column (8), we replace month fixed effects with month-by-district fixed effects. In column (9), we replace month fixed effects with year-by-month (time) fixed effects, while substituting district fixed effects with more granular neighborhood fixed effects. This means we are controlling for any unobserved, time-invariant characteristics specific to each neighborhood, as well as for broader time trends that vary by year and month. This is a very strict test, as it accounts for any time-invariant unobserved heterogeneity at the neighborhood level. Our results continue to describe an additional premium in house prices in certain localities (following the Kahramanmaraş earthquake) thanks to the fact that they correspond to relatively safer İstanbul neighborhoods. This provides strong evidence that our main result is not confounded by unobserved neighborhood-specific factors or broader time trends.

Moreover, İstanbul stands as a large metropolitan region hosting a vast amount of population. It covers residential areas across both sides of Bosphorus Strait that can quite differ in terms of housing market dynamics and urban densification (Dökmeci et al., 2003; Önder et al., 2004; Ozus et al., 2007; Ahsan and Sadak, 2021). Therefore, in the last part of robustness checks, we repeat the baseline estimations in an iterative manner by keeping neighborhoods in only European and Asian-side districts. In columns (10) and (11), we observe that housing markets in both European and Asian neighborhoods have undergone significant rises in prices, following the Kahraman-

maras earthquake, if the related localities are perceived safer in terms of earthquake proneness relative to others. The coefficient is still positive and statistically significant in both subsamples (columns (10) and (11), indicating that the earthquake premium for safer neighborhoods is a phenomenon observed on both the European and Asian sides of Istanbul.¹⁸

In column (12), instead of continuous Earthquake Risk variable, we follow a conventional DiD estimation by creating a binary proxy categorizing treatment and control groups with high and low degrees of earthquake proness. In this context, we create binary earthquake risk, which takes the value of one for houses located in neighborhoods with Earthquake Risk scores of 3, 4 and 5, whereas it takes the value of zero for the remaining houses covered by the sample. This simplifies the analysis by creating a clear distinction between “treated” (lower-risk) and “control” (higher-risk) groups. In other words, this specification estimates the average difference in house price changes between the low-risk and high-risk groups after the earthquake, relative to the difference before the earthquake. The resultant coefficient implies house prices in low-risk areas increased by approximately 4.8% more than house prices in high-risk areas after the earthquake, relative to the pre-earthquake difference. This finding provides further evidence of an economically significant earthquake premium incorporated into house prices, aligning with our main results.

To ensure that our results are invariant to the choice of denomination of outcome variable, we undertake additional analyses. In column (13), we use $\ln(\text{Real House Prices})$ as the dependent variable, which is created using TurkStat CPI index for İstanbul province. In row (14), we adopt a different deflator to generate $\ln(\text{Real House Prices})$ by employing İstanbul Trade Union (İTO) White Goods price index. In both cases, our main inferences remain qualitatively same. In column (15), we exclude some control variables including Pool, Kitchen, Security to repeat our estimation to ensure the choice of these house controls do not entirely drive the results. In column (16), we control for a potential confounding factor by including the district-level ratio of mortgaged sales to total house sales (based on the data sourced from TurkStat) as an additional covariate. We still document a significant price premium associated with the houses located in the safer İstanbul neighborhoods following the distant earthquake.

¹⁸ It is important to distinguish the interpretation of the standalone coefficient on Earthquake Risk from that of the interaction term $\text{Post} \times \text{Earthquake Risk}$. Since Earthquake Risk is a time-invariant neighborhood-level measure, its coefficient reflects pre-existing cross-sectional price differences across neighborhoods rather than the post-earthquake reassessment of seismic risk. These baseline price gradients may be shaped by several local characteristics, including accessibility, coastal amenities, socioeconomic composition, housing-stock quality, neighborhood centrality, and urban density. This distinction is particularly relevant when we estimate the model separately for the European and Asian sides of İstanbul. The two sides of the city differ substantially in terms of historical development, locational amenities, transportation networks, and the spatial distribution of high-value neighborhoods. Therefore, the opposite signs of the standalone Earthquake Risk coefficient in the two subsamples should not be interpreted as contradictory evidence regarding the earthquake-risk premium. Instead, they indicate that the pre-existing relationship between neighborhood safety scores and price levels differs across the two submarkets. The relevant treatment coefficient, $\text{Post} \times \text{Earthquake Risk}$, remains positive and statistically significant in both subsamples, suggesting that the Kahramanmaraş earthquake increased the relative premium for safer neighborhoods on both sides of İstanbul.

In column (17), we attempt to show that the shift in cost of mortgages due to monetary policy steps, which coincides with our treatment timeline, does not create a strong confounding factor. Hence, we first obtain time series data on sector-level weighted average cost of mortgages from CBRT, and then create a new control variable monitoring the variation in mortgage interest rates. When we repeat the estimations based on an extended version of Eq. (1) with this new control variable, we continue to report significant results for the earthquake risk premium in housing market. The potential change in migration patterns following the distant earthquake may confound the results. In order to address the potential concerns regarding this factor, given the data limitations at regional level, we obtain the population growth rate at district-level for İstanbul province for the recent period (from 2023 to 2024). In column (18), using this indirect proxy as a new control variable, we still observe a positive and significant premium in the pricing of housing market. Thus, while the earthquake period coincided with macroeconomic developments including monetary policy shifts and evolving supply-side conditions, the stability of results across specifications controlling for mortgage rates, mortgaged sales ratios and neighborhood fixed effects suggests that the confounding role of such factors might be somewhat limited.¹⁹ Accordingly, we interpret the coefficient on $\text{Post} \times \text{Earthquake Risk}$ as capturing the differential post-earthquake change in house prices associated with TCIP-measured seismic safety, rather than as the isolated structural effect of earthquake risk alone.

Overall, the analyses presented in this subsection demonstrate the robustness of our main findings to increasingly stringent controls and alternative model specifications. These results strongly suggest that the earthquake served as a catalyst, prompting a reassessment of earthquake risk and a shift in housing preferences across İstanbul.²⁰ Additionally, we implemented the whole set of robustness checks to the baseline estimations pertaining to house rent pricing dynamics following the earthquake and reached similar conclusions.

Internal Validity of Empirical Design

The baseline model given in Eq. (1) is expected to produce reliable results if the parallel trends condition holds. This assumption, as often tested in studies focusing on real estate dynamics, suggests that the trend in the outcome variable for the treatment

¹⁹ To further test the confounding role of migration tendencies and exposure to financing conditions, we have undertaken triple differences estimations constructed with district-level variables for population growth rate and the ratio of mortgaged sales to total house sales. Our findings continue to show indistinguishable patterns in treatment effects concerning earthquake risk premium based on the heterogeneity of districts in terms of population change and financial conditions. In addition, we used triple differences design to analyze the heterogeneous impacts on house rents, which still showed insignificant results. We thank the anonymous reviewer for these suggestions.

²⁰ These specifications mitigate concerns that the baseline coefficient is driven only by broad market conditions, credit-market developments, or time-invariant neighborhood characteristics. Nevertheless, we acknowledge that these checks cannot fully eliminate all possible omitted-variable concerns, especially those arising from unobserved time-varying neighborhood-level shocks. We therefore interpret the results as consistent with a post-earthquake reassessment of seismic risk rather than as definitive evidence of a purely structural earthquake-risk effect.

group would have evolved similarly with respect to the trend in the control group in the absence of the treatment (Dumeignil, 2022; Garriga et al., 2023; Bui et al., 2024; Ganduri & Maturana, 2024). However, as suggested by Holland (1986), we cannot explicitly prove the validity of the parallel trends assumption in observational studies due to the fundamental problem of causal inference, which states that we are not able to monitor what the counterfactual outcome of treated units would have been in the case that they had not received the treatment. Nevertheless, as often implemented in prior studies, we indirectly evaluate the plausibility of the parallel trends assumption by using two methods.

First, we conduct a graphical analysis to visualize the course of the outcome variable in the treatment and control groups before the occurrence of the shock of interest. In detail, we calculate the average house price (per square meter) separately for houses located in the group of neighborhoods with relatively lower earthquake risk (for which the Earthquake Risk variable assumes the values of 3, 4, or 5) and in the group of neighborhood with comparably higher earthquake risk (for which Earthquake Risk variable takes the values of 1 or 2). In Fig. 4, we graph the evolution of mean house prices for the aforementioned binary classification. Prior to the Kahramanmaraş earthquake, the average pricing tendencies for both groups followed a similar trend, indicating parallel trajectories and no significant divergence in pricing behavior between high-risk and low-risk neighborhoods. However, following the earthquake, we observe a clear divergence in price levels.²¹ Neighborhoods with lower earthquake risk began experiencing a proportionally higher increase in house prices compared to high-risk neighborhoods. This post-shock divergence suggests a shift in buyer preferences, as market participants likely placed greater emphasis on safety, leading to a premium for properties in low-risk areas.

Second, we undertake a randomization inference analysis following the procedure outlined by Heß (2017). In this case, we begin with the most saturated specification defined by Eq. (1). Then, we create a series of pseudo Earthquake Risk variables by randomly assigning the risk scores to İstanbul neighborhoods. After randomizing the treatment allocation, we utilize pseudo Earthquake Risk variables to repeat the baseline estimations to predict how earthquake risk is embedded in the pricing of the housing sector. We re-iterate this procedure 1000 times to record a set of pseudo estimates regarding the coefficient assigned to the $Post * Earthquake Risk$ interaction variable. Table 4 provides the summary statistics characterizing the empirical distribution of pseudo coefficients. Notably, the actual treatment effect (0.0231) remains beyond the distribution of such pseudo estimates, which further supports the validity of our empirical design. By demonstrating that the actual treatment effect cannot be replicated under randomized risk allocations, this analysis supports the interpretation that the divergence in house prices between low-risk and high-risk neighborhoods is related to the post-earthquake increase in the salience of seismic risk.

²¹ It would not be surprising to see the aggregated price levels diverging with a delay given that the house purchases are significant economic decisions, which require intensive searching, the securing of necessary financing and other procedural steps. It is also expected to observe the divergence peaking just after the beginning of summertime given that this trend is typical in housing markets following the end of school terms and the routine re-shuffling of civil servants among other factors.

Furthermore, we follow an event study approach (Fig. 5). This estimation covers the original sample period of the study (January 2022–February 2024). In this context, we augment the specification in Eq. (1) with the interaction of time indicators relative to the occurrence of Kahramanmaraş earthquake in 2023Q1 (defined in quarterly terms) with Earthquake Risk variable, while one quarter before the event is taken as the reference period (2022Q4). The estimation results imply that the coefficients are insignificant and hover around zero threshold prior to the Kahramanmaraş earthquake incident, while they become significantly positive afterwards (Table 9 of the Appendix). In turn, this finding renders additional support to the validity of parallel trends.

In addition, to assess whether transaction patterns are consistent with the gradual emergence of the earthquake risk premium, we report the quarterly distribution of appraisal counts separately for high-risk and low-risk neighborhoods (Table 10). The relative share of transactions across the two groups remains notably stable throughout the sample period, hovering around 64–67% for high-risk and 33–36% for low-risk neighborhoods. This compositional stability, combined with the marked decline in overall transaction volume in the quarters following the earthquake, is consistent with the notion that housing purchases entail significant search, financing, and procedural frictions that delay the full capitalization of updated risk perceptions into prices. These patterns corroborate the event study evidence showing a gradual build-up of the earthquake risk premium rather than an abrupt structural break.

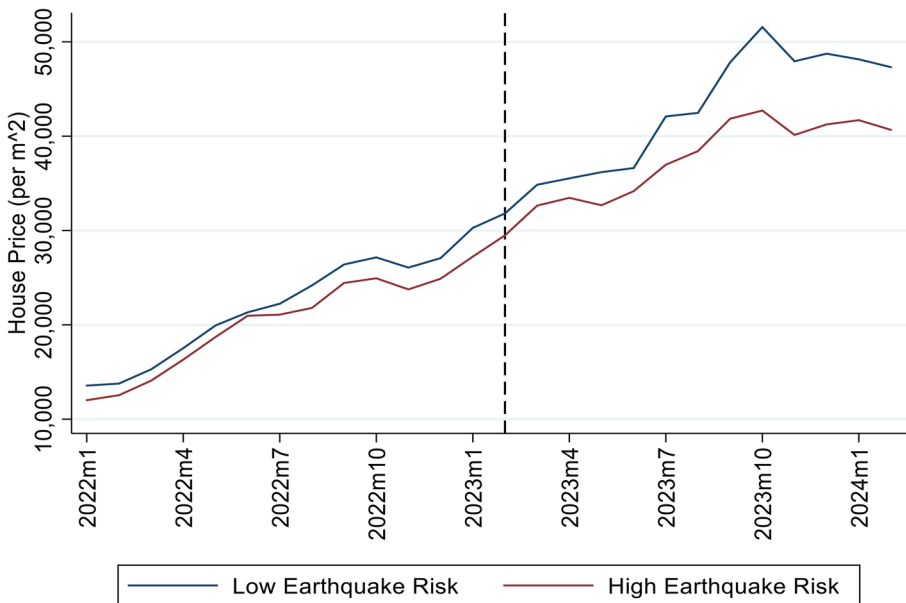


Fig. 4 Parallel Trends. Note: This chart demonstrates the course of averaged house prices for two separate categories of house prices depending on earthquake risk. Particularly, we gather İstanbul neighborhoods with TCIP risk map scores of 1 and 2 into “High Earthquake Risk” group, while neighborhoods with risk scores of 3, 4 and 5 are defined in “Low Earthquake Risk” group. Then, we calculate the average house prices (per m²) and assess their trends before and after the occurrence of Kahramanmaraş Earthquake Sequence (that is depicted with vertical black-colored dashed line)

Table 4 Randomization Inference

	(1) Placebo Estimates (Post x Earthquake Risk)
Min	-0.0129
1 st percentile	-0.0116
5th percentile	-0.0077
10th percentile	-0.0064
25th percentile	-0.0031
Median	0.0000
75th percentile	0.0033
90th percentile	0.0062
95th percentile	0.0082
99th percentile	0.0104
Max	0.0141
Actual Coefficient	0.0231

This table provides the randomization inference analysis performed to support the validity of parallel trends assumption. In the first step, we create a pseudo Earthquake Risk variable by randomizing the assignment of earthquake risk scores, while keeping the timing of the exogenous variation in risk perception (due to Kahramanmaraş earthquake) same (in other words, by keeping Post variable same). Then, we repeat the estimations based on the saturated specification in Eq. (1) and record the treatment coefficient of interest (related to the term Post x Earthquake Risk). In the following step, we repeat this procedure 1000 times to end up with a distribution of pseudo effects. This table shows a detailed characterization of pseudo coefficients' distribution together with the actual coefficient reported in column (4) of Table 2

Additional Analysis

This sub-section presents the additional empirical analyses. The previous strand of literature considers earthquake risk as an input for the determination of house rents in addition to house prices. Nakagawa et al. (2007) find that house rents are substantially lower in earthquake-prone areas of Tokyo. Singh (2019) examines the case of California and finds that rents decline following the delineation of the fault zone. To evaluate how house rents are influenced by the spatial distribution of earthquake risk in İstanbul, following the perception change after the Kahramanmaraş earthquake in 2023, we use the following model specification:

$$\begin{aligned} \ln(House\ Rent)_{i,t,d,n} = & \alpha + \beta_1 * Post_t \\ & + \beta_2 * Earthquake\ Risk_{d,n} \\ & + \beta_3 * Post_t * Earthquake\ Risk_{d,n} \\ & + \gamma X_{i,t,d,n} + \mu_t + \pi_d + \epsilon_{i,t,d,n} \end{aligned} \quad (2)$$

where $\ln(House\ Rent)_{i,t,d,n}$ refers to the natural logarithm of the renting price (per square meter) quoted for house i at time t located in district d neighborhood n . All modeling parameters including other variable definitions, house controls, the set of fixed effects and standard error clustering are exactly the same as Eq. (1). The estimations for house rents are shown in Table 5. In column (1), we follow a basic specification, whereas column (2) adds the set of house controls. Along the similar lines, column (3) extends the model with month fixed effects, while column (4) augments with district fixed effects. The information on house rents is taken from the

same administrative micro-level dataset provided by CBRT. This dataset entails rent values that stem from the same set of appraisal reports used to obtain house prices. These reports approximate house rent values by considering the rent levels in nearby houses and the heterogeneity in house characteristics.

In all estimations, it turns out that the main $Post * Earthquake Risk$ interaction variable has a positive and highly significant coefficient. In turn, this hints that houses situated in low-risk neighborhoods (for which Earthquake Risk variable takes higher values) bring more rent yield in the post-Kahramanmaraş earthquake episode relative to houses situated in high-risk neighborhoods (for which Earthquake Risk variable takes lower values).²² This finding is in line with the notion that İstanbul housing sector has recently experienced a rent premium governed by the exposure to earthquake risk in addition to the price premium observed in the market. Importantly, this shift may reflect renters' willingness to pay higher rents for perceived safety and reduced exposure to potential disasters, even if they do not own the property.

Furthermore, we return to our baseline analysis concerning the link between earthquake risk and house prices and explore potential social, economic and financial mechanisms. In particular, the essence of this extended analysis is centered on socio-economic development of the neighborhood, the leverage of house acquisition transactions and the historical evaluation of construction codes applicable to Turkish

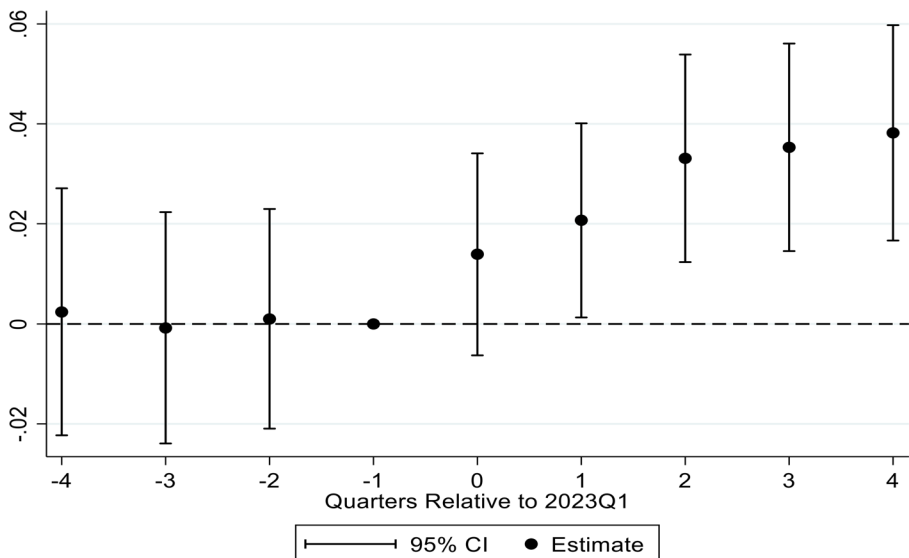


Fig. 5 Event Study Analysis. Note: This chart demonstrates the results of event study analysis. The empirical model is saturated with time indicators representing the relative quarter to the Kahramanmaraş earthquake (2023Q1) that are interacted with the variable . The chart demonstrates point estimates attached to interaction terms together with 95% confidence intervals

²² Our inferences concerning the effect on house rents do not diverge considerably when time fixed effects are used instead of month fixed effects.

housing sector.²³ With this in mind, we adopt a triple-differences model defined as follows:

$$\begin{aligned} \ln(\text{House Price})_{i,t,d,n} = & \alpha + \beta_1 * \text{Post}_t \\ & + \beta_2 * \text{Earthquake Risk}_{d,n} \\ & + \beta_3 * \text{Post}_t * \text{Earthquake Risk}_{d,n} \\ & + \beta_4 * \text{Channel} + \beta_5 * \text{Post}_t * \text{Channel} \\ & + \beta_6 * \text{Earthquake Risk}_{d,n} * \text{Channel} \\ & + \beta_7 * \text{Post}_t * \text{Earthquake Risk}_{d,n} \\ & * \text{Channel} + \gamma X_{i,t,d,n} + \epsilon_{i,t,d,n} \end{aligned} \quad (3)$$

where $\ln(\text{House Price})_{i,t,d,n}$, Post_t and $\text{Earthquake Risk}_{d,n}$ are defined the same way they are described in Eq. (1). Channel refers to the proxy variable used to anticipate the underlying mechanisms. In the first stage, we replace *Channel* with $\text{Social}_{d,n}$ which takes the value of one if socio-economic status of neighborhood n (of district d) is expressed as either letter grades of A+, A, A-, B+ or B (based on the 8-scale grading classification (available in the İstanbul Metropolitan Municipality) comprising possible grades of A+, A, A-, B+, B, C+, C, D and E), otherwise assuming the value of zero.²⁴ In the second stage, we substitute *Channel* with $\text{Credit}_{i,t,d,n}$, which is the continuous loan-to-value ratio conveyed by the appraisal report. In the third and last stage, we swap Channel with $\text{Construction 2007}_{i,t,d,n}$ receiving the value of one for the houses that had been built after 2007 when the construction code was reformed to make the construction process more accommodating for earthquake risks.

As in the baseline specification, the TCIP score captures neighborhood-level variation in relative seismic safety, and the interaction with the post-earthquake indicator captures how this variation became differentially capitalized into prices after the Kahramanmaraş earthquake. In the triple-difference specification, the coefficient on $\text{Post} \times \text{Earthquake Risk} \times \text{Channel}$ should therefore be interpreted as heterogeneity in this post-earthquake capitalization effect across the relevant channel, rather than as a separate causal estimate of earthquake risk itself.

We present the estimations of triple differences model in Table 6, where the estimations for each particular mechanism is repeated with and without hedonic house controls in a stepwise manner. In columns (1) and (2), we find that the triple interaction term assumes a negative and statistically significant coefficient. This shows that additional earthquake risk premium in house prices observed in low-risk neighborhoods is mitigated when socio-economic status of areas is considerably high. A

²³ The triple-difference estimates should be interpreted with additional caution. These specifications are intended to explore whether the baseline post-earthquake risk premium varies across socioeconomic, financial, and regulatory channels. They are not intended to redefine the earthquake-risk measure or to serve as the primary identification test. Compared with the baseline difference-in-differences model, the triple-difference specification requires sufficient independent variation across three dimensions: time, TCIP-measured earthquake risk, and the channel variable. If the channel variable is measured with error, is correlated with neighborhood amenities, or captures multiple mechanisms at once, the resulting estimates may be less precise and more sensitive across specifications.

²⁴ Accessed via <https://data.istanbul/dataset/2023-yili-istanbul-ses-skoru>.

Table 5 Estimations for Rent Prices

	(1) ln(House Rent)	(2) ln(House Rent)	(3) ln(House Rent)	(4) ln(House Rent)
Post x Earthquake Risk	0.0272*** (0.0068)	0.0222*** (0.0065)	0.0226*** (0.0062)	0.0219*** (0.0045)
Post	0.6309*** (0.0172)	0.6325*** (0.0161)	0.6666*** (0.0152)	0.6838*** (0.0111)
Earthquake Risk	0.0147 (0.0162)	0.0159 (0.0137)	0.0198 (0.0137)	-0.0005 (0.0121)
# of observations	97,637	97,637	97,637	97,637
House Controls	No	Yes	Yes	Yes
Month FE	No	No	Yes	Yes
District FE	No	No	No	Yes
Adj. R ²	0.268	0.398	0.457	0.610

This table provides the effect of earthquake risk on house rents through the regression estimations in line with Eq. (2). Our overall sample spans the interval between January 2022 and February 2024. In detail, the sample is composed of observations belonging to 139,913 unique house appraisals from 836 neighborhoods of 39 districts in İstanbul. In all columns, the dependent variable is taken as ln(House Rent), which is defined as the natural logarithmic transformation of house rents. Post takes the value of one after the occurrence of Kahramanmaraş earthquake, otherwise zero. Earthquake Risk monitors the (time-invariant) neighborhood-level proness to earthquake risk obtained from TCIP risk map (with the discrete scores ranging from 1 to 5 where lower values correspond to higher degree of earthquake risk). The main coefficient of interest is attached to the interaction term Post x Earthquake Risk. Column (1) estimates the most parsimonious specification. Column (2) adds the set of house characteristics, Rooms, Elevator, Pool, Carpark, Security, Heating, Washroom, Kitchen, House Age, to the estimations as control variables. Column (3) uses month fixed effects, while column (4) uses district fixed effects. Variable definitions and data sources are given in Table 1, whereas summary statistics are given in Table 7 of the Appendix. Standard errors clustered at neighborhood level are shown in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10%, respectively

plausible explanation is that wealthier neighborhoods may already have better infrastructure, awareness, and resources to manage seismic risks, making these areas less sensitive to changes in risk perception following the earthquake. This finding highlights the role of socio-economic disparities in shaping housing market responses to natural disasters and suggests that urban resilience is not only about physical safety but also about socio-economic capacity.

When we examine columns (3) and (4), we see that the extra margin embedded in house prices of low-risk geographical units is somewhat amplified when the house purchasing transaction involves relatively higher leverage, despite the fact that statistical significance is diminished when house controls are incorporated.²⁵ Finally, yet importantly, in columns (5) and (6), we document that house price premium due

²⁵ The triple-interaction loses significance once hedonic controls are added, indicating that the apparent amplification of the safety premium through leverage is largely attributable to the composition of high-LTV transactions, which concentrate in newer, post-2007-code units that carry the premium for structural reasons. We therefore do not claim a robust credit-conditions channel; the construction-code channel (columns 5–6), which is stable to the inclusion of controls, is the mechanism the data support. We separately rule out a time-series interest-rate confound in column (17) of Table 3.

to the shift in perception about earthquake risks is stronger for a house that has been built after the change in construction code in 2007. This finding underscores the importance of structural resilience in influencing buyer preferences. Properties built under the revised code are perceived as safer due to improved seismic standards, making them particularly attractive in the post-earthquake period. This result also highlights the role of regulatory interventions in shaping market responses to natural disasters.²⁶

Conclusion

This paper examines how households in İstanbul respond to new information about seismic risks, using the Kahramanmaraş earthquake sequence as a catalyst for updated risk perceptions among home buyers. It compares pre- and post-earthquake prices and rents of residential properties in neighborhoods with varying levels of seismic risk, despite İstanbul not being directly impacted by the earthquakes. Our study area, İstanbul, however, is also highly vulnerable to earthquake risk, lying along the North Anatolian Fault Zone, one of the world's most active earthquake zones. The city also bears the legacy of the devastating 1999 Kocaeli earthquake, making its housing market particularly sensitive to shifts in risk perceptions.

Our findings indicate that the Kahramanmaraş earthquake sequence, although it occurred in southeastern Türkiye, was followed by a differential change in property values across İstanbul neighborhoods with different levels of TCIP-measured seismic safety. Using a granular dataset of official real estate appraisal reports, coupled with seismic hazard maps and socio-economic indicators, we employ a difference-in-differences approach to uncover significant market responses. Our findings underscore that while high-risk neighborhoods experienced weaker price growth or even declines, low-risk areas saw heightened demand, reflecting a clear shift in buyer preferences towards safer properties. Additionally, rents followed a similar trend, with a rent premium emerging in lower-risk neighborhoods.

Our results further reveal the importance of structural and socio-economic factors in moderating market responses. Properties built after the 2007 Turkish Earthquake Code experienced lower discounts or even premiums compared to older structures, highlighting the role of construction standards in shaping risk perceptions. Similarly, the earthquake risk premium observed in house prices was less pronounced in wealthier neighborhoods, suggesting that socio-economic capacity and infrastructure play a critical role in mitigating perceived risks. These findings are consistent across various robustness checks and alternative model specifications, lending credibility to our conclusions.

²⁶ To get further evidence for these channels, we use the baseline specification for sub-sample analysis as shown in Table 11 of the Appendix. Our results continue to imply a stronger effect for the subset of observations corresponding to lower socio-economic development and construction timeline after 2007.

Table 6 Heterogeneity Analysis

	(1) ln(House Price)	(2) ln(House Price)	(3) ln(House Price)	(4) ln(House Price)	(5) ln(House Price)	(6) ln(House Price)
Post x Earthquake Risk	0.0312*** (0.0078)	0.0326*** (0.0069)	0.0155** (0.0068)	0.0209*** (0.0061)	0.0062 (0.0094)	0.0067 (0.0087)
Post	0.6289*** (0.0195)	0.6083*** (0.0175)	0.5886*** (0.0159)	0.5582*** (0.0145)	0.6389*** (0.0198)	0.6197*** (0.0188)
Earthquake Risk	0.0449** (0.0185)	0.0364*** (0.0127)	0.0289 (0.0204)	0.0263 (0.0163)	0.0397 (0.0279)	0.0356 (0.0222)
Social	0.4779*** (0.0918)	0.3723*** (0.0899)				
Post x Social	0.0005 (0.0306)	0.0088 (0.0312)				
Earthquake Risk x Social	-0.0108 (0.0399)	-0.0080 (0.0403)				
Post x Earthquake Risk x Social	-0.0324** (0.0137)	-0.0358*** (0.0137)				
Credit			-0.4990*** (0.0513)	-0.4096*** (0.0369)		
Post x Credit			0.0217 (0.0408)	0.1213*** (0.0375)		
Earthquake Risk x Credit			-0.0229 (0.0212)	-0.0205 (0.0171)		
Post x Earthquake Risk x Credit			0.0425** (0.0173)	0.0159 (0.0172)		
Construction 2007					0.1010 (0.0633)	0.1254** (0.0574)
Post x Construction 2007					-0.0372 (0.0242)	-0.0273 (0.0216)
Earthquake Risk x Construction 2007					-0.0134 (0.0268)	-0.0123 (0.0225)
Post x Earthquake Risk x Construction 2007					0.0230** (0.0110)	0.0218** (0.0099)
# of observations	139,913	139,913	139,913	139,913	139,913	139,913
House Controls	No	Yes	No	Yes	No	Yes
Adj. R ²	0.369	0.512	0.304	0.479	0.264	0.456

This table provides the channel analysis in line with Eq. (3). Our overall sample spans the interval between January 2022 and February 2024. In detail, the sample is composed of observations belonging to 139,913 unique house appraisals from 836 neighborhoods of 39 districts in İstanbul. In all columns, the dependent variable is taken as $\ln(\text{House Price})$, which is defined as the natural logarithmic transformation of house prices (per m^2). Post takes the value of one after the occurrence of Kahramanmaraş earthquake, otherwise zero. Earthquake Risk monitors the (time-invariant) neighborhood-level proness to earthquake risk obtained from TCIP risk map (with the discrete scores ranging from 1 to 5 where lower values correspond to higher degree of earthquake risk). The main coefficient of interest is attached to the triple interaction term Post x Earthquake Risk x Channel. To proxy channel variable, we first use the variable Social in columns (1) and (2), which takes the value of one if the house is located in a neighborhood with socio-economic status score of at least B (based on data from İstanbul Metropolitan Municipality), otherwise zero. In columns (3) and (4), we replace channel with credit, which is defined as the ratio of loan amount to total house value (based on data from CBRT). In columns (5) and (6), we substitute Channel with Construction 2007, which assumes the value of one if the house is built after the enactment of new construction code in 2007, otherwise zero. Columns (1), (3) and (5) estimates the most parsimonious specifications, while columns (2), (4) and (6) add the set of house characteristics, Rooms, Elevator, Pool, Carpark, Security, Heating, Washroom, Kitchen, House Age, to the estimations as control variables. Variable definitions and data sources are given in Table 1, whereas summary statistics are given in Table 7 of the Appendix. Standard errors clustered at neighborhood level are shown in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10%, respectively

These findings have important policy implications. First, as suggested by previous studies such as Naoi et al. (2009) and Kawabata et al., (2022), if the authorities had conducted a comprehensive assessment of earthquake risk and fully disseminated that information to the public, the earthquakes would have had a limited effect on changing the risk perceptions of people living over 1,000 km away from the affected region. Therefore, the increase in risk premiums associated with high-hazard areas after the event suggests a need for more information transparency and stronger disclosure requirements. They should require all actors in the real estate sector, including the government, municipalities, mortgage lenders, sellers, and real estate agencies, to effectively disclose any natural hazard-related risk, and provide clear risk information to potential buyers. This should be an ongoing effort to maintain appropriate risk perception levels rather than relying on sporadic events to raise awareness. Particularly, enhanced risk communication strategies should be developed for lower socio-economic status areas.

Our findings also confirm the need to reform the earthquake insurance system to incorporate additional local risk assessments, as seismic risk zone maps have not reflected the true nature of these risks in house prices before the event. To form a more comprehensive understanding of earthquake and earthquake-related risks, additional information needs to be collected, mapped, and disseminated on several key areas, such as soil and geotechnical conditions (e.g., local soil types, rock formations, and liquefaction likelihood) and topographic and geological features (e.g., areas with steep slopes or fault lines that may have higher risks of landslides or ground ruptures). Relatedly, given the magnitude of the devastating losses, the government should work to increase the penetration of the compulsory Turkish Catastrophe Insurance Pool across Türkiye, which was around 50% in the affected area and 61% in İstanbul at that time. Insurance programs might need to be restructured to account for socio-economic differences, with subsidized insurance programs implemented for lower-income areas in high seismic risk zones.

Another key policy implication is that regulatory bodies should prioritize the enforcement and promotion of updated construction building codes, as we have shown that households in İstanbul incorporated the Turkish Earthquake Code of 2007 into their home prices. Offering incentives to both developers and homeowners would result in widespread code adherence over time, leading to increased urban resilience, reduced vulnerability to natural disasters, and potentially lower insurance premiums for compliant properties. Furthermore, a long-term mitigation strategy for earthquake risk could involve relocating some of the population from higher-risk areas by incentivizing businesses and companies to establish offices and factories in less earthquake-prone regions. Additionally, investment in infrastructure reinforcement in high-risk zones is essential, with priority given to improving earthquake resilience infrastructure in areas with lower socioeconomic status.

Appendix

Table 7 Summary Statistics

Panel A: Pre-Kahramanmaras Earthquake		Obs.	Mean	Std. Dev	p5	p95
ln(House Price)		87,530	9.742	0.585	8.829	10.781
Post		87,530	-	-	-	-
Earthquake Risk		87,530	2.172	1.009	1.000	4.000
Rooms		87,530	2.449	1.056	1.000	4.000
Elevator		87,530	0.699	0.459	0.000	1.000
Pool		87,530	0.176	0.381	0.000	1.000
Carpark		87,530	0.520	0.499	0.000	1.000
Security		87,530	0.288	0.453	0.000	1.000
Heating		87,530	2.057	0.704	1.000	4.000
Washroom		87,530	1.331	0.602	1.000	2.000
Kitchen		87,530	1.034	0.215	1.000	1.000
House Age		87,530	13.607	13.379	0.000	45.000
Panel B: Post-Kahramanmaras Earthquake		Obs.	Mean	Std. Dev	p5	p95
ln(House Price)		52,383	10.408	0.478	9.688	11.289
Post		52,383	-	-	-	-
Earthquake Risk		52,383	2.165	1.017	1.000	4.000
Rooms		52,383	2.465	1.003	1.000	4.000
Elevator		52,383	0.713	0.452	0.000	1.000
Pool		52,383	0.204	0.403	0.000	1.000
Carpark		52,383	0.545	0.497	0.000	1.000
Security		52,383	0.316	0.465	0.000	1.000
Heating		52,383	2.150	0.839	1.000	4.000
Washroom		52,383	1.364	0.604	1.000	2.000
Kitchen		52,383	1.041	0.205	1.000	1.000
House Age		52,383	12.549	12.498	0.000	39.000

This table provides the summary statistics of the variables used in the main regressions. It provides the information on the measures such as mean, standard deviation, 5th percentile and 95th percentile values. Panel (A) gives the detailed summary statistics belonging to the pre-Kahramanmaras earthquake, while panel (B) gives the same statistics for the post-Kahramanmaras earthquake period

Table 8 Estimations with Separated Earthquake Risk Scores

	ln(House Price)
Post x Earthquake Risk 2	0.0229* (0.0123)
Post x Earthquake Risk 3	0.0601*** (0.0127)
Post x Earthquake Risk 4	0.0616*** (0.0206)
Post x Earthquake Risk 5	0.0383 (0.0368)
Post	0.6824*** (0.0089)
Earthquake Risk 2	-0.0496* (0.0253)
Earthquake Risk 3	0.0168 (0.0374)
Earthquake Risk 4	-0.0107 (0.0479)
Earthquake Risk 5	0.1125 (0.0788)
# of observations	139,913
House Controls	Yes
Month FE	Yes
District FE	Yes
Adj. R ²	0.726

This table provides the estimations for the specification extended by adding separated Earthquake Risk scores to Eq. (1). Our overall sample spans the interval between January 2022 and February 2024. In detail, the sample is composed of observations belonging to 139,913 unique house appraisals from 836 neighborhoods of 39 districts in Istanbul. The dependent variable is taken as ln(House Price), which is defined as the natural logarithmic transformation of house prices (per m²). Post takes the value of one after the occurrence of Kahramanmaraş earthquake, otherwise zero. Earthquake Risk monitors the (time-invariant) neighborhood-level proneness to earthquake risk obtained from TCIP risk map (with the discrete scores ranging from 1 to 5 where lower values correspond to high level of earthquake risk). The separated indicators take the value of one for observations corresponding to the specific Earthquake Risk scores, otherwise zero. These include Earthquake Risk 1, Earthquake Risk 2, Earthquake Risk 3, Earthquake Risk 4 and Earthquake Risk 5. We add the set of house characteristics, Rooms, Elevator, Pool, Carpark, Security, Heating, Washroom, Kitchen, House Age, to the estimations as control variables. We use month and district fixed effects. Variable definitions and data sources are given in Table 1, whereas summary statistics are given in Table 7 of the Appendix. Standard errors clustered at neighborhood level are shown in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10%, respectively

Table 9 Event Study Estimation Results

	ln(House Price)
2022Q1 x Earthquake Risk	0.0024 (0.0126)
2022Q2 x Earthquake Risk	-0.0008 (0.0118)
2022Q3 x Earthquake Risk	0.0010 (0.0112)
2022Q4 x Earthquake Risk	...
2023Q1 x Earthquake Risk	0.0139*** (0.0103)
2023Q2 x Earthquake Risk	0.0207** (0.0099)
2023Q3 x Earthquake Risk	0.0331*** (0.0106)
2023Q4 x Earthquake Risk	0.0353*** (0.0106)
2024Q1 x Earthquake Risk	0.0383*** (0.0032)
# of observations	139,913
House Controls	Yes
Time FE	Yes
District FE	Yes
Adj. R ²	0.788

This table provides the estimations for the event study analysis presented in Fig. 5. Our overall sample spans the interval between January 2022 and February 2024. In detail, the sample is composed of observations belonging to 139,913 unique house appraisals from 836 neighborhoods of 39 districts in İstanbul. The dependent variable is taken as ln(House Price), which is defined as the natural logarithmic transformation of house prices (per m²). Earthquake Risk monitors the (time-invariant) neighborhood-level proneness to earthquake risk obtained from TCIP risk map (with the discrete scores ranging from 1 to 5 where lower values correspond to high level of earthquake risk). This variable is interacted with quarterly time indicators representing the relative quarter to Kahramanmaraş earthquake (2023Q1), whereas the quarter 2022Q4 is omitted for normalization purposes. We add the set of house characteristics, Rooms, Elevator, Pool, Carpark, Security, Heating, Washroom, Kitchen, House Age, to the estimations as control variables. We use time and district fixed effects. Variable definitions and data sources are given in Table 1, whereas summary statistics are given in Table 7 of the Appendix. Standard errors clustered at neighborhood level are shown in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10%, respectively

Table 10 Quarterly Distribution of Transactions by Earthquake Risk Group

Date	High Risk Neighborhoods	Low Risk Neighborhoods	High Risk Neighborhoods (Share)	Low Risk Neighborhoods (Share)
2022q1	12,846	7208	64.06	35.94
2022q2	18,351	10,319	64.01	35.99
2022q3	9763	4867	66.73	33.27
2022q4	12,809	6033	67.98	32.02
2023q1	12,114	6779	64.12	35.88
2023q2	9979	5464	64.62	35.38
2023q3	6992	3562	66.25	33.75
2023q4	5014	2537	66.40	33.60
2024q1	4006	1990	66.81	33.19

This table reports the quarterly number of house appraisals and the corresponding percentage shares for high-risk and low-risk neighborhood groups. Following the binary classification used in Fig. 4 and column (12) of Table 3, high-risk neighborhoods are defined as those with TCIP earthquake risk scores of 1 or 2, while low-risk neighborhoods correspond to scores of 3, 4, or 5. Shares (in percent) are calculated as the proportion of each group's transaction count relative to the total number of transactions in the respective quarter. The sample spans from January 2022 to February 2024. The Kahramanmaraş earthquake occurred in February 2023 (2023Q1). The relative compositional stability of transaction shares across the two groups, alongside the marked decline in overall transaction volume in the post-earthquake quarters, is consistent with the presence of search, financing, and procedural frictions that delay the full capitalization of updated risk perceptions into housing prices.

Table 11 Additional Heterogeneity Analysis

	(1) ln(House Price)	(2) ln(House Price)	(3) ln(House Price)	(4) ln(House Price)	(5) ln(House Price)	(6) ln(House Price)
Post x Earthquake Risk	0.0115 (0.0104)	0.0291*** (0.0049)	0.0269*** (0.0049)	0.0206*** (0.0067)	0.0250*** (0.0055)	0.0195*** (0.0071)
Post	0.6437*** (0.0231)	0.6706*** (0.0129)	0.6679*** (0.0122)	0.6414*** (0.0148)	0.6646*** (0.0131)	0.6434*** (0.0155)
Earthquake Risk	0.0523** (0.0265)	-0.0025 (0.0132)	-0.0027 (0.0133)	0.0105 (0.0162)	0.0036 (0.0164)	0.0099 (0.0152)
Sample	Social=1	Social=0	Credit>0	Credit=0	Construc- tion2007=1	Construc- tion2007=0
# of observations	52,848	87,065	69,784	70,129	99,510	40,403
House Controls	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R ²	0.681	0.730	0.730	0.714	0.753	0.691

This table provides the alternative heterogeneity analysis by decomposing the sample into sub-groups based on channel variables. Our overall sample spans the interval between January 2022 and February 2024. In detail, the sample is composed of observations belonging to 139,913 unique house appraisals from 836 neighborhoods of 39 districts in Istanbul. In all columns, the dependent variable is taken as ln(House Price), which is defined as the natural logarithmic transformation of house prices (per m²). Post takes the value of one after the occurrence of Kahramanmaraş earthquake, otherwise zero. Earthquake Risk monitors the (time-invariant) neighborhood-level proneness to earthquake risk obtained from TCIP risk map (with the discrete scores ranging from 1 to 5 where lower values correspond to higher degree of earthquake risk). In column (1), we use the house observations belonging to sub-group for which social variable takes the value of one, while column (2) represents the sub-group where social variable takes the value of zero. The variable social takes the value of one if the house is located in a neighborhood with socio-economic status score of at least B (based on data from İstanbul Metropolitan Municipality), otherwise zero. In column (3), we use the house observations belonging to sub-group for which credit variable assumes positive values, while column (4) represents the sub-group where credit variable equals to zero. The variable credit is defined as the ratio of loan amount to total house value. In column (5), we use the house observations belonging to sub-group for which Construction 2007 variable takes the value of one, while column (6) represents the sub-group for which Construction 2007 variable is zero. The variable Construction 2007 assumes the value of one if the house is built after the enactment of new construction code in 2007, otherwise zero. In all columns, we use month and district fixed effects. In all columns, we add the set of house characteristics, Rooms, Elevator, Pool, Carpark, Security, Heating, Washroom, Kitchen, House Age, to the estimations as control variables. Variable definitions and data sources are given in Table 1, whereas summary statistics are given in Table 7 of the Appendix. Standard errors clustered at neighborhood level are shown in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10%, respectively.

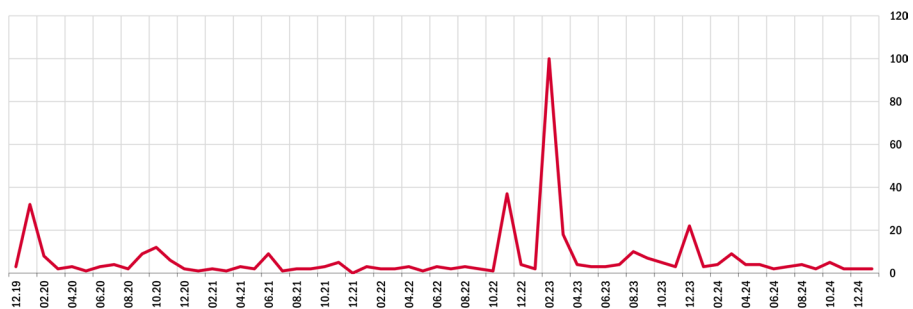


Fig. 6 Google Trends Data for “İstanbul Earthquake”. Note: This figure plots the Google Trends search interest index for the query “İstanbul Deprem” (English: “İstanbul earthquake”). Google Trends reports a normalized measure of search intensity scaled from 0 to 100, where 100 denotes the peak search volume within the selected time window and geography; values are relative (not absolute counts) and depend on the chosen query, region, and period. The series is included as a proxy for public attention/salience regarding earthquake risk in Istanbul. Search intensity exhibits a pronounced spike following the February 2023 Kahramanmaraş Earthquake Sequence, whereas earlier episodes generate comparatively smaller movements

Acknowledgments The authors would like to thank Cumali Turkmenoglu for his valuable efforts in the visualisation of the Istanbul map used in this study.

Funding Open access funding provided by Copenhagen Business School. The authors declare that they did not receive any funding for this research.

Declarations

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors. Therefore, no ethical approval was required for this research.

Competing interests The author has no relevant financial or non-financial interests to disclose.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Abbasoglu, H. B., & Kalkan, B. (2025). The Saliency of Disaster: How Experience Outweighs Information in Pricing Earthquake Risk. Available at SSRN. <https://ssrn.com/abstract=4747530>
- Abrokwhah, M., Bian, X., Devos, E., & Sun, X. (2026). Does Economic Freedom Hedge Against Bad Luck? Evidence from Natural Disasters and Local Housing Price Appreciation. *The Journal of Real Estate Finance and Economics*, 1–37.
- Ahsan, M. M., & Sadak, C. (2021). Exploring housing market and urban densification during COVID-19 in Turkey. *Journal of Urban Management*, 10(3), 218–229.
- Bernknopf, R. L., Brookshire, D. S., & Thayer, M. A. (1990). Earthquake and volcano hazard notices: An economic evaluation of changes in risk perceptions. *Journal of Environmental Economics and Management*, 18(1), 35–49.
- Beron, K. J., Murdoch, J. C., Thayer, M. A., & Vijverberg, W. P. M. (1997). An analysis of the housing market before and after the 1989 Loma Prieta earthquake. *Land Economics*, 73(1), 101–113.
- Boelhouwer, P., & van der Heijden, H. (2018). The effect of earthquakes on the housing market and the quality of life in the province of Groningen, the Netherlands. *Journal of Housing and the Built Environment*, 33, 429–438. <https://doi.org/10.1007/s10901-018-9600-y>
- Bond, S., & Dermisi, S. (2017). Using GIS to measure the impact of the Canterbury earthquakes on house prices in Christchurch, NZ. *International Journal of Disaster Resilience in the Built Environment*, 8(2), 123–138. <https://doi.org/10.1108/IJDRBE-05-2015-0027>
- Brookshire, D. S., Thayer, M. A., Tschirhart, J., & Schulze, W. D. (1985). A test of the expected utility model: Evidence from earthquake risks. *Journal of Political Economy*, 93(2), 369–389.
- Bui, N., Wen, L., & Sharp, B. (2024). House prices and flood risk exposure: An integration of hedonic property model and spatial econometric analysis. *Journal of Real Estate Finance and Economics*, 69(1), 100–131.
- Cheung, R., Wetherell, D., & Whitaker, S. (2018). Induced earthquakes and housing markets: Evidence from Oklahoma. *Regional Science and Urban Economics*, 69, 153–166. <https://doi.org/10.1016/j.regsciurbeco.2018.01.004>
- Deng, G., Gan, L., & Hernandez, M. A. (2015). Do natural disasters cause an excessive fear of heights? Evidence from the Wenchuan earthquake. *Journal of Urban Economics*, 90, 79–89. <https://doi.org/10.1016/j.jue.2015.10.002>

- Dökmeci, V., Önder, Z., & Yavas, A. (2003). External factors, housing values, and rents: Evidence from survey data. *Journal of Housing Research*. <https://doi.org/10.1080/2167034x.2003.12461361>
- Dumeignil, C. (2022). The impact of cross-border labor mobility on real estate price trends: A natural experiment. *International Regional Science Review*, 45(1), 108–132.
- Durán, N., & Elhorst, J. P. (2023). Induced earthquakes and house prices: The role of spatiotemporal and global effects. *Journal of Geographical Systems*, 25, 157–183. <https://doi.org/10.1007/s10109-022-00403-8>
- Emre, Ö., Duman, T. Y., Özalp, S., et al. (2018). Active fault database of Turkey. *Bulletin of Earthquake Engineering*, 16, 3229–3275. <https://doi.org/10.1007/s10518-016-0041-2>
- Fang, L., Li, L., & Yavas, A. (2023). The impact of distant hurricane on local housing markets. *The Journal of Real Estate Finance and Economics*, 66(2), 327–372.
- Fang, L., Li, L., Scofield, D., & Yavas, A. (2026). Hurricane-induced risk contagion in commercial real estate: Evidence from Hurricane Sandy. *Real Estate Economics*. <https://doi.org/10.1111/1540-6229.70034>
- Fekrazad, A. (2019). Earthquake-risk salience and housing prices: Evidence from California. *Journal of Behavioral and Experimental Economics*, 78, 104–119.
- Ganduri, R., & Maturana, G. (2024). Do property rehabs affect neighboring property prices? *Journal of Urban Economics*, 143, 103694.
- Garriga, C., Gete, P., & Tsouderou, A. (2023). The economic effects of real estate investors. *Real Estate Economics*, 51(3), 655–685.
- Gibbons, S., Heblich, S., & Timmins, C. (2021). Market tremors: Shale gas exploration, earthquakes, and their impact on house prices. *Journal of Urban Economics*. <https://doi.org/10.1016/j.jue.2020.103313>
- Heß, S. (2017). Randomization inference with Stata: A guide and software. *The Stata Journal*, 17(3), 630–651.
- Hidano, N., Hoshino, T., & Sugiura, A. (2015). The effect of seismic hazard risk information on property prices: Evidence from a spatial regression discontinuity design. *Regional Science and Urban Economics*, 53, 113–122. <https://doi.org/10.1016/j.regsciurbeco.2015.05.005>
- Holland, P. W. (1986). Statistics and causal inference. *Journal of the American Statistical Association*, 81(396), 945–960.
- Huang, Y. (2021). Salience of hazard disclosure and house prices: Evidence from Christchurch, New Zealand. *Regional Science and Urban Economics*, 88, Article 103679. <https://doi.org/10.1016/j.regsciurbeco.2021.103679>
- Hussain, E., Kalaycıoğlu, S., Milliner, C. W. D., et al. (2023). Preconditioning the 2023 Kahramanmaraş (Türkiye) earthquake disaster. *Nature Reviews Earth & Environment*, 4(5), 287–289. <https://doi.org/10.1038/s43017-023-00411-2>
- Jung, J. H., & Smith, G. (2021). Earthquakes and home prices: The Napa and Ridgecrest quakes. *Journal of Housing Research*, 31(1), 74–87.
- Kawabata, M., Naoi, M., & Yasuda, S. (2022). Earthquake risk reduction and residential land prices in Tokyo. *Journal of Spatial Econometrics*, 3, Article 5. <https://doi.org/10.1007/s43071-022-00020-z>
- Keskin, B., Dunning, R., & Watkins, C. (2017). Modelling the impact of earthquake activity on real estate values: A multi-level approach. *Journal of European Real Estate Research*, 10(1), 73–90.
- Koster, H. R. A., & van Ommeren, J. (2015). A shaky business: Natural gas extraction, earthquakes, and house prices. *European Economic Review*, 80, 120–139.
- Lee, S., & Zheng, S. (2026). Annoyed, but not alarmed: Sea level rise, chronic inundation, and coastal housing markets. *The Journal of Real Estate Finance and Economics*, 1–27.
- Mothorpe, C., & Wyman, D. (2021). What the frack? The impact of seismic activity on residential property values. *Journal of Housing Research*, 30(1), 34–58. <https://doi.org/10.1080/10527001.2020.1827579>
- Murdoch, J. C., Singh, H., & Thayer, M. (1993). The impact of natural hazards on housing values: The Loma Prieta earthquake. *Journal of the American Real Estate and Urban Economics Association*, 21(2), 167–187.
- Nakagawa, M., Saito, M., & Yamaga, H. (2007). Earthquake risk and housing rents: Evidence from the Tokyo Metropolitan Area. *Regional Science and Urban Economics*, 37(1), 87–99.
- Nakagawa, M., Saito, M., & Yamaga, H. (2009). Earthquake risks and land prices: Evidence from the Tokyo metropolitan area. *The Japanese Economic Review*, 60(2), 208–222. <https://doi.org/10.1111/j.1468-5876.2008.00438>
- Naoi, M., Seko, M., & Sumita, K. (2009). Earthquake risk and housing prices in Japan: Evidence before and after massive earthquakes. *Regional Science and Urban Economics*, 39(6), 658–669.
- Önder, Z., Dökmeci, V., & Keskin, B. (2004). The impact of public perception of earthquake risk on Istanbul's housing market. *Journal of Real Estate Literature*, 12(2), 181–194.

- Ortega, F., & Taşpınar, S. (2018). Rising sea levels and sinking property values: Hurricane Sandy and New York's housing market. *Journal of Urban Economics*, 106, 81–100.
- Ozus, E., Dokmeci, V., Kiroglu, G., & Egdemir, G. (2007). Spatial analysis of residential prices in Istanbul. *European Planning Studies*, 15(5), 707–721.
- Parsons, T., Toda, S., Stein, R. S., Barka, A., & Dieterich, J. H. (2000). Heightened odds of large earthquakes near Istanbul: An interaction-based probability calculation. *Science*, 288(5466), 661–665.
- Şengör, A. M. C., Tüysüz, O., İmren, C., Sakıncı, M., Eyidoğan, H., Görür, G., Le Pichon, X., & Rangin, C. (2005). The North Anatolian fault: A new look. *Annual Review of Earth and Planetary Sciences*, 33, 37–112.
- Shi, S., & Naylor, M. (2023). Perceived earthquake risk in housing purchases. *Journal of Housing and the Built Environment*, 38, 1761–1787. <https://doi.org/10.1007/s10901-023-10012-6>
- Singh, R. (2019). Seismic risk and house prices: Evidence from earthquake fault zoning. *Regional Science and Urban Economics*, 75, 187–209.
- Sirmans, C. S., Sirmans, G. S., Smersh, G. T., & Winkler, D. T. (2025). Perceptions of climate change and the pricing of disaster risk in commercial real estate. *Journal of Real Estate Finance and Economics*. <https://doi.org/10.1007/s11146-025-10015-w>
- Willis, K. G., & Asgary, A. (1997). The Impact of Earthquake Risk on Housing Markets: Evidence from Tehran Real Estate Agents. *Journal of Housing Research*, 8(1), 125–136. <http://www.jstor.org/stable/24833635>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Authors and Affiliations

Oguzhan Cepni^{1,2,3}  · Ismail H. Genc⁴  · Lokman Gunduz⁵ · Muhammed Hasan Yılmaz^{6,7}

✉ Oguzhan Cepni
oce.eco@cbs.dk

Lokman Gunduz
lgunduz68@gmail.com

¹ Department of Economics, Copenhagen Business School, Copenhagen, Denmark

² Center for Economics and Policy Studies, Istinye University, Istanbul, Türkiye

³ Ostim Technical University, Ankara, Türkiye

⁴ American University of Sharjah, Sharjah, United Arab Emirates

⁵ Department of Management, Fatih Sultan Mehmet Vakif University, Istanbul, Türkiye

⁶ University of St Andrews, St Andrews, United Kingdom

⁷ Central Bank of the Republic of Türkiye, Istanbul, Türkiye