Changes in Public Risk Perception after a Large Disaster: Evidence from the Housing Market*

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Abstract

The unprecedented damage caused by the Great East Japan Earthquake and nuclear disaster greatly altered people's awareness of risk not only in directly affected areas but also in unaffected areas as well. Changes in risk perception of future earthquakes can influence people's location choice, which in turn can be capitalized into the real estate prices. This study focuses on the relationship between earthquake risk and real estate prices in unaffected areas before and after the earthquake in order to explore how large-scale natural disasters influence people's perception toward disaster risk.

We use large-scale property transaction data covering periods both before and after the earthquake, together with the earthquake risk indexes by the Tokyo Metropolitan Government, to estimate a hedonic model. Three features are worth noting about our data. First, our property data includes exact location of each property, so that the data can be matched with the geographical index of earthquake risk that is measured at the fairly detailed geographic level. Second, our data spans from 2008 to 2017, covering periods both before and after the 2011 earthquake. Third, given our very large sample sizes, we can explore price responses to potential hazard at disaggregated levels such as region or property types. All three of these features allow us to explore whether and to what extent the relationship between risk information and real estate prices is changed after a large disaster.

Our empirical findings are summarized as follows. First, we found that after the 2011 earthquake

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house prices are dropped more in relatively risky areas than in safer areas for condominium units sold in these areas. In comparison, we could not find any evidence that housing rents are decreased more in risky areas as compared to safer areas. These results suggest that changes in risk perception are found for prospective homebuyers, rather than for tenants. Second, post-quake price drops are particularly eminent for properties built under the new earthquake resistance standards or for those properties located on upper floors. Third, price drops in risky areas are substantial for relatively large houses (three- or more bedroom houses). Since people in houses with three- or more bedrooms are more likely to have children, our results suggest that households with children could alter their risk perception after the disaster. Fourth, we found that significant post-quake price discounts can be observed for three to five years following the earthquake, after which price levels return to their pre-quake baseline.

Keywords: hedonic analysis, earthquake risk, risk perception, housing market

1 Introduction

The unprecedented damage caused by the Great East Japan Earthquake and subsequent tsunami could substantially changed people's awareness of potential disaster risk in Japan. The purpose of this paper is to explore how large-scale natural disasters influence people's perception toward disaster risk in unaffected areas.

Figure 1 illustrates trends in Google search frequencies for two keywords that are associated disaster risks—"earthquake risk index" and "Tokyo inland earthquake"—in Tokyo, covering periods both before and after the 2011 earthquake. It shows that search frequencies for these two keywords dramatically increased in the immediate aftermath of the Great East Japan Earthquake (March 2011, dashed line).[1] This suggests that people's perception toward potential risk of future earthquakes increased in Tokyo, a city that received hardly any direct damage from the 2011 earthquake.[2]

(Figure 1 here)

Changes in risk perception of future earthquakes can influence people's location choice, which, in turn, can be capitalized into the real estate prices. This paper focuses the relationship between earthquake risk and house prices in Tokyo metropolitan area, and tests whether the relationship is changed after the Great East Japan Earthquake in 2011.

The frequency of large-scale earthquakes is low, which makes it difficult to predict if they will cause widespread damage. Consumer risk perception thus greatly depends on subjective assessments, and is therefore subject to bias (Lichtenstein et al., 1978; Kask and Maani, 1992; Rogers, 1997). Under these circumstances, actual occurrences of earthquakes can provide additional information for consumers to make assessments of low-frequency disaster risk.

In this study, we examine the relationship between earthquake risk and real estate prices before and after the Great East Japan Earthquake in the Tokyo metropolitan area. Specifically, we use large-scale property transaction data covering periods both before and after the earthquake, together with the earthquake risk indexes by the Tokyo Metropolitan Government, to estimate a hedonic model.

Three additional features are worth noting about our data. First, our property data includes exact location of each property, so that the data can be matched with the geographical index of

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[1] Figure 1 also shows that the search frequencies have several spikes after the 2011 earthquake. The number of searches for both keywords increased in September 2011 and March 2012. In both cases, the number of searches was greatly influenced by an extensive media coverage on the Great East Japan Earthquake, coinciding with a September 1 disaster prevention day, and in the case of the latter, the period marking one year after the earthquake. In addition, there was a dramatic increase in the number of searches only for the keywords "earthquake risk index" in September 2013. This was due to the release of the seventh "Survey of District-based Vulnerability to Earthquake Disaster" by the Tokyo Metropolitan government that same month.

[2] Direct damage to Tokyo from the Great East Japan Earthquake was minor, but that does not mean it was left completely unharmed. According to the 2017 White Paper on Fire Service, the number of dead and injured in Tokyo was 8 and 119 people, respectively. The number of homes and other buildings that were completely destroyed was 20, with a further 223 buildings partially destroyed (FDMA, 2017).

earthquake risk that is measured at the fairly detailed geographic level. Second, our data spans from January 2001 to September 2017, covering periods both before and after the 2011 earthquake. Third, given our very large sample sizes, we can explore price responses to potential hazard at disaggregated levels such as region or property types. All three of these features allow us to explore whether and to what extent the relationship between risk information and real estate prices is changed after a large disaster.

The results of our analysis indicate the following. First, we found that house prices in risky areas are declined relative to those in safer areas after the earthquake. In comparison, we could not find any evidence that the relationship housing rents and earthquake risk is changed after the earthquake. These results suggest that changes in risk perception are found for prospective homebuyers, rather than for tenants. Second, price drops are particularly eminent for properties built under the new earthquake resistance standards, or for properties located on upper floors. Third, price drops in risky areas can be observed for relatively large houses (three- or more bedroom houses). Since people in houses with three- or more bedrooms are more likely to have children, our results suggest that households with children could alter their risk perception after the disaster. Fourth, we found that price drops in risky areas were observed for several years after the earthquake but after that, prices reverted to their pre-quake levels.

The organization of this paper is as follows below. In Section 2, we briefly discuss the mechanism by which large-scale disasters can influence the people’s risk perception and real estate prices in unaffected areas. In Section 3, we explain our dataset and variables, and present an empirical model. In Section 4, we present our estimation results, and offer a possible interpretation. Finally, in Section 5, we describe our conclusions and remaining issues.

2 Changes in Risk Perception after Large Disasters

How do people change their perception toward the risk of potential disasters after the actual occurrence of large disasters in other areas? First, it is possible that assessments of the likelihood of earthquake occurrence (hazard) may change with the occurrence of an actual disaster. Studies of people’s risk perception of low-frequency, high-consequence hazards such as earthquakes offer two different possibilities for the direction of changes after the occurrence of an actual disaster. For example, Lichetenstein et al. (1978) and Viscusi (1985) show that people without disaster experiences tend to overestimate the probability of rare disasters, suggesting that people might decrease their probability assessments after an actual disaster. On the other hand, according to studies such as those by Kask and Maani (1992), and Kunreuther and Pauly (2004), people tend to recognize probability as likely being zero, and act accordingly, when objective probability falls below some threshold. If information stemming from an actual disaster works in the direction of eliminating people’s risk perception bias, people might raise their probability assessments after an event.

Second, knowing actual damage circumstances through media coverage or other means may result in a revised assessment of vulnerability to disasters. That is, even if there is no change in assessment of the likelihood of disaster, assessing the occurrence and scale of damage will change when a single disaster occurs.

Third, it is possible that people's attitude to risk changes with the occurrence of a disaster. For example, recent studies, such as by Cameron and Shah (2015) and Said et al. (2015), suggest the possibility of greater risk avoidance by individuals who have experienced a disaster.[3] Risk-averse individuals demand large premiums for dwelling in risk-prone regions, and therefore, even if there is no tentative change in risk assessments, disasters may subsequently alter the relationship between risk and real estate prices.

There have been a limited but growing number of studies investigating whether the relationship between disaster risk information and real estate prices is changed after a large disaster.[4] Beron et al. (1997) examined the impact of the 1989 Loma Prieta earthquake in the San Francisco Bay Area, and found that the negative impact of risk indexes on real estate prices was greater prior to the earthquake. These results imply that residents lowered their risk assessment of future earthquakes after the disaster.

On the other hand, Gu et al. (2018) examined the impact of Great Hanshin–Awaji Earthquake in 1995 on risk perception toward nearby active fault.[5] Their empirical results suggest that land prices substantially decreased in areas closer to the Uemachi fault—which is a potential source of future earthquakes but not directly related to the 1995 earthquake—after the disaster. Kawawaki (2007) studied changes in the relationship between earthquake risk and real estate prices over time using the area affected by the Great Hanshin–Awaji Earthquake, showing a relative decrease in land prices in several years after the earthquake. Naoi et al. (2009) showed that large-scale earthquakes can lead to a decrease in housing prices in nearby areas that did not receive direct damage. These results suggest that residents in unaffected areas might increase their risk assessments after a disaster.[6]

Another line of research examines the impact of the Fukushima nuclear disaster on people's risk perception by looking at real estate prices in areas close to nuclear power plants outside Fukushima (Boes et al., 2015; Fink and Stratmann, 2015; Zhu et al., 2016; Bauer et al, 2017; Kawaguchi and Yukutake, 2017; Tanaka and Zabel, 2018). Some of these studies showed that real estate prices in the vicinity of nuclear power plants outside Fukushima decreased after the incident. However, magnitude, spatial scope, and statistical significance of the impact differs substantially

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[3] On the other hand, regarding the subject of this study (the Great East Japan Earthquake), results of analyses, such as that by Hanaoka et al. (2015), show that the degree of risk avoidance after an earthquake decreases as individuals gain more experience of major damage (intensity) due to an earthquake.

[4] Our literature review here primarily focuses on papers regarding earthquakes. However, there are also previous studies focusing on floods and other types of natural disasters (Bin and Polasky, 2004; Kousky, 2010; Bin and Landry, 2013; Atreya et al., 2013). In addition, while the impact of past disasters on real estate prices (i.e., a hedonic approach) is widely investigated in the literature, there are also several studies investigating its impact on subjective risk assessment of disaster victims (Lo and Cheung, 2015), the disaster prevention behavior such as insurance purchases (Jiang et al. 2013; Gallagher, 2014; Kousky, 2017), and disaster awareness and preparedness (Naoi et al., 2012).

[5] In addition, Nakagawa et al. (2009) analyzed the relationship between earthquake risk and land prices in the Tokyo metropolitan area during a period extending before and after the Great Hanshin–Awaji Earthquake. This analysis did not find the core reason for changes due to the 1995 earthquake in the relationship between earthquake risk and land prices.

[6] In the context of the Great East Japan Earthquake, Ishizuka and Yokoi (2017) studied whether the relationship between earthquake risk and land prices is changed after the earthquake.

across studies depending on factors such as the area analyzed and the type of real estate traded (property for rental or sale, land, etc.).

3 Data and Empirical Model

3.1 Earthquake Risk Index

A location-specific risk of potential earthquake damage is taken from the “Survey of District-based Vulnerability to Earthquake Disaster” released by the Tokyo Metropolitan Government.[7] The survey provides a location specific earthquake risk index that ranks each administrative district—called Cho-Cho-Moku in Japanese (hereafter CCM)—on a five-point scale, with 1 being the safest and 5 being the riskiest. The CCMs are administrative districts subordinate to local governments, largely corresponding to seven-digit postal codes.[8] The risk index was first released in November 1975, and has subsequently been updated roughly every five years, incorporating the latest data and methodologies. In the following analysis, we use the index reported in the sixth wave of the survey (published in February 2008), which was available at the time of the Great East Japan Earthquake.

The survey reports two distinct risk indices, each of which captures different aspects of earthquake risk: building collapse and fire. The index for building collapse measures the likelihood of buildings to collapse or tilt from earthquake tremors. They are assessed based on factors such as building composition and ground/soil characteristics in the neighborhood. For example, risky areas tend to have structures with poor earthquake resistance quality or have soil conditions susceptible to the seismic tremors. The index of fire risk, on the other hand, measures the likelihood of fire outbreak or spread due to the occurrence of an earthquake. They are assessed based on factors such as fire resistance quality and density of buildings in the neighborhood. For example, risky areas tend to have more wooden buildings or have higher structure density without sufficient architectural firebreaks (such as wide streets or parks). The survey also reports the combined risk index that account for both aspects of earthquake risk. We use the combined risk index in our baseline analysis, and use two specific indices (building collapse risk and fire risk) in a supplementary analysis.

Figure 2 shows the geographical distribution of the combined risk. High-risk areas are particularly concentrated in the Northeastern part of Tokyo, which is usually considered as the Tokyo’s inner-city district located along two major rivers (Arakawa and Sumidagawa rivers). These areas have ground characteristics particularly susceptible to earthquakes (such as alluvial lowlands and valley bottom lowlands) and are mostly residential with a dense crowding of old wooden buildings.

(Figure 2 here)

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[7] Original survey results and related documents are available from http://www.toshiseibi.metro.tokyo.jp/bosai/chousa_6/home.htm.

[8] The most recent survey released in 2018 assesses earthquake risk for 5,177 CCMs in Tokyo.

3.2 Housing Transaction Data

Our housing transaction data is provided by the Real Estate Transaction Promotion Center (RETPC), which is an association of real estate agents. The RETPC provides the largest Multiple Listing Service (MLS) in Japan—called Real Estate Information Network System (hereinafter, REINS)[9]. As of December 2017, the REINS database provides 324,192 sales listings and 541,005 rental listings.

We extract the final transaction information (such as contract sales prices and rents) from the REINS listing database. Our dataset includes all property transactions in Tokyo's 23 districts ("ku" in Japanese) registered in the REINS database. In our main empirical analysis, we focus on property transactions made between March 11, 2008 and March 10, 2013, covering periods both before and after the 2011 earthquake. The data include both sales and rental transactions of condominium units. After eliminating observations with missing values, we have 53,181 sales transactions and 268,743 rental transactions.[10] Table 1 shows the summary statistics for sales and rental transactions. On average, we do not find any major changes in property characteristics before and after the earthquake, except for the age of buildings.

(Table 1 here)

3.3 Empirical Model

Our benchmark regression model is given as follows.

$$log\, p_{ijt} = \alpha_k + \sum_{r \in \{M,H\}} \{\beta^r 1[Z_j = r] + \delta^r D_t \cdot 1[Z_j = r]\} + \gamma' X_{it} + \phi D_t + u_{ijt}, \qquad (1)$$

where i indexes property, j represents the CCM in which a property is located, k is the district, and t is the year of transaction. Unless otherwise noted, transaction years are defined using March 11 as a reference date in the following analysis. That is, the 2011 dummy takes the value of one for property transactions made between March 11, 2011 and March 10, 2012. p_{ijt} is the transaction price (for sales transactions) or contracted rent (for rental transactions), and D_t is a dummy variable that takes the value of one for properties traded after the Great East Japan Earthquake (on or after March 11, 2011). Z_j is a CCM's local risk index, where low risk areas $(r = L)$ are CCMs with risk index being 1, medium-risk areas $(r = M)$ are CCMs with risk

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[9] There are four independent MLSs operated by the RETPC covering different regions in Japan. Our transaction data is taken from the REINS for East Japan, which covers listings in 17 prefectures in northeastern Japan including Tokyo.

[10] We also exclude outliers in terms of transaction prices and rents. For sales transactions, we exclude observations with transaction prices higher than one billion JPY or lower than one million JPY. For rental transactions, we exclude observations with monthly rents higher than 10 million JPY or lower than 10 thousand JPY. These sample restrictions are, however, minor in comparison to our total sample sizes. Number of excluded observations are 27 for sales transactions and 1,148 for rental transactions.

index being 2, and high-risk areas $(r = H)$ are CCMs with risk index being 3 or higher (Nakagawa et al., 2009).[11] $1[Z_j = r]$ is a dummy variable that takes the value of one if $Z_j = r$ and zero otherwise.

In Equation (1), β represents the baseline relationship between earthquake risk and house prices prior to the earthquake. Since we omit the dummy variable for low risk areas $(r = L)$ as a reference category, β^M and β^H show price differentials in medium- and high-risk areas, respectively, as compared to low risk areas during periods before the 2011 earthquake.

Our parameter of interest is δ, which represents the additional changes in price differentials after the 2011 earthquake. Since we omit the dummy variable for low risk areas $(r = L)$ as a reference category, the coefficient estimates for δ^M and δ^H represent the additional price differentials in medium- and high-risk areas, relative to low-risk areas, observed after the 2011 earthquake.[12] For example, δ^M represents post-quake changes in average house price/rent in areas with medium risk $(r = M)$ after the earthquake, relative to that in areas with low risk $(r = L)$. If people's relative risk assessment for locations with different earthquake risk changed after the earthquake, δ^M and δ^H can be different from zero. In particular, if people change their risk assessment in a way that they think already risky areas even riskier after the earthquake, the value of these coefficients will be negative.

In Equation (1), we also control for a set of property characteristics, X_{it}, which include building age, earthquake resistance quality,[13] distance to four major stations in Tokyo, floor space in square meter, floor level in which a unit is located[14], and the type of structure.[15] In order to control for unobserved location heterogeneity and location-specific time trends, we add district fixed effects (α_k), district×calendar year fixed effects, and district×month fixed effects.

A major concern of the analysis based on Equation (1) is bias due to unobservable factors specific to geographical divisions smaller than districts. As shown in Figure 2, areas with high earthquake risk are geographically concentrated. Within-district heterogeneity correlated with local earthquake risk as well as price/rent levels can bias our estimates based on Equation (1). In

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[11] Ranks 3, 4 and 5 are combined in the following analysis because there are few CCMs with ranks 4 or 5. In particular, properties located in CCMs with the highest risk index (rank 5) are less than 2.5% of the full sample. As a result, when we examine the impacts of ranks 4 and 5 separately, they are not always estimated precisely enough to draw strong evidence. However, we find that the overall pattern of estimation results is roughly consistent with our main findings shown below.

[12] Note that post-quake changes in average price/rent in the safest areas are captured by the coefficient ϕ of the post-quake dummy variable, D_t.

[13] This variable takes the value of one if the unit was built on or after June 1, 1981, and zero otherwise. Since earthquake building code was substantially upgraded by the 1981 amendment of the Building Standard Law, structures built under the new building code are considered to have better seismic resistance quality.

[14] The floor location is available only for condominium units, and thus is not included in explanatory variables in estimates using detached housing as samples.

[15] The type of structure in the data are wood frame, block, steel frame, reinforced concrete (RC), steal reinforced concrete (SRC), precast concrete (PC), hard precast concrete (HPC), light gauge steel frame, and others. We used dummy variables for each of these categories in the analysis.

order to address this issue, our preferred specification controls for fixed effects at the CCM levels.

$$log\, p_{ijt} = \alpha_j + \sum_{r\in\{M,H\}} \delta^r D_t \cdot I\big[Z_j = r\big] + \gamma' X_{it} + \phi D_t + u_{ijt}, \tag{2}$$

In Equation (2), α_j represents the fixed effects for CCMs, which controls for any time-invariant heterogeneity at the CCM level. Since the earthquake risk index Z_j is a variable measured at the CCM level, β's are omitted from Equation (2). On the other hand, δ^r represents changes in price differentials in medium- and high-risk areas, relative to low-risk areas, observed after the 2011 earthquake as in Equation (1).

4 Empirical Results

4.1 Benchmark Results

Table 2 shows our benchmark regression results based on Equations (1) and (2). Columns [1] and [2] are the results for sales transactions, and columns [3] and [4] are the results for rental transactions. For each transaction type, we run two regressions; one controlling for the district-level fixed effects (first column), and the other controlling for the CCM-level fixed effects (second column). We report the cluster-robust standard errors for all of the results below using the CCMs as a unit of clustering.

(Table 2 here)

Regarding the relationship between earthquake risk index and house prices/rents before the earthquake, significant price discounts in medium- and high-risk areas are found for rental transactions but not for sales transactions. As compared to low-risk areas, housing rents in medium- and high-risk areas are discounted by about 2 percent. Our estimates are basically in line with those in previous studies. Nakagawa et al. (2007), using the same earthquake risk index as ours, show that housing rents in high-risk areas are significantly discounted as compared to low-risk areas.

In comparison, we do not find any statistically significant relationship between earthquake risk and transaction prices for condominium units for sale. One explanation is that, due to differences in the quality of building located in risky areas (such as their level of earthquake resistance performance), a price discount for condominium units in risky areas may be partially offset by the better quality of building in these areas. We will discuss this point further in the next section.

When we look at the coefficient for the interaction term between post-earthquake dummy and earthquake risk index (δ_r), the following results are obtained. First, sales prices are decreased more in high-risk areas as compared to low-risk areas after the 2011 earthquake. According to our estimation results with CCM fixed effects, average price in low-risk areas decreased by about 2.6 percent (i.e., coefficient estimate on post-quake dummy variable). Medium- and high-risk areas saw an additional decrease by about 1.9 percent, leading to an overall decrease of about 4.5 percent. Second, price discounts in risky areas are not observed for rental transactions. Given that there already exist significant price discounts in high-risk areas prior to the earthquake, it is possible that there were no additional changes to risk perception for rental housing.

Overall, we find significant post-quake price discounts in risky areas for sales condominium units, but not for rental units.

4.2 Heterogeneous Price Responses

A. Earthquake Resistance Standards

As discussed earlier, a major concern for the results presented in Table 2 is that there might be some property-specific factors that correlate with price/rent levels as well as with location-specific earthquake risk. For example, housing units located in risky areas tend to have better earthquake resistance quality as a result of owner's self-protection investment, and better housing quality can raise the transaction prices. This can offset the impact of location-specific risk on house prices. Furthermore, if property owners in risky areas invest more in their properties after the earthquake, post-quake price changes in risky areas (i.e., δ_r's in Equations (1) and (2)) can also be biased.

Conversely, post-quake changes in risk perception of existing residents and the resulting relocation decision can influence the composition of listed properties in the market. For example, existing homeowners in risky areas might choose to move out if they think their home has insufficient earthquake resistance quality. As a result, properties listed on the market might have lower quality after the earthquake than before, particularly in risky areas. In either case, failing to control for the earthquake resistance quality of each property can bias our estimates based on Equations (1) and (2).

In order to address the problem, we focus on the observable earthquake resistance standards as defined by the Building Standard Law. Specifically, the legal earthquake resistance standards were substantially upgraded by the 1981 amendment to the Building Standard Law. As a result, structures built under the new building code are considered to have better seismic resistance quality. In the following analysis, we examine whether the impact of earthquake risk on housing prices differs between properties under new and old earthquake resistance standards.

Table 3 shows the estimation results. We estimated separate regressions for properties under old and new earthquake standards.

(Table 3 here)

The results from column [1] indicate that, prior to the earthquake, significant price discounts are observed for sales units built under the old standards, but not for units built under the new standards. These results are consistent with Nakagawa et al. (2007) showing that the buildings under the old standard is more sensitive to earthquake risk than those under the new standard. In comparison, the results for rental units show that significant rent discounts are observed for units built under the new standards, but not for units built under the old standards (column [3]).

The results from columns [2] and [4], which control for fixed effects at the CCM level, indicate that post-quake changes in price/rent discounts are found for newer properties for sale, but not in other cases. Post-quake price discounts in medium- and high-risk areas increased by about 2.3 and 2.5 percent for sales transactions of units built under the new standards (column [2]).

B. Property Size

As mentioned in section 2, several past studies have suggested the possibility that experience with disaster raises people's level of risk avoidance (Cameron and Shah, 2015; Said et al., 2015). Our dataset, however, does not include resident's attributes, and thus difficult to directly test this hypothesis.

In this section, we compare the results for one- and two-bedroom houses with the results for three- or more bedroom houses. Presumably, families with children are more likely to live in houses with three or more bedrooms, and those without children are more likely to live in smaller houses. Families with children may respond more sensitively to disaster risk indexes. In this case, it is possible that properties with more rooms are more greatly influenced by earthquake risk indexes after an earthquake.[16]

Table 4 shows our estimation results. The results indicate that post-quake changes in price/rent discounts can be found only for sales units with three or more bedrooms when we control for the CCM-level fixed effects (columns [2] and [4]).

(Table 4 here)

C. Floor levels

Changes in risk perception after the earthquake can differ depending on the certain property characteristics. One such characteristics is the floor level on which a property is located. People might prefer to live in lower floors as shocks are felt stronger in upper floors (Deng et al., 2015).

Table 5 compares the results for units on the fifth floor or lower with the results for units on the sixth floor or higher. It is found that the significant post-quake changes in price discounts can be observed for sales properties on upper floors, but not for other cases.

(Table 5 here)

4.3 Alternative Earthquake Risk Measures

As explained in Section 3.1, earthquake risk index used in our benchmark model combines two distinct aspects of earthquake risk: risk of building collapse and that of fire spreading after the earthquake. Public perception towards these two aspects of earthquake risk are interrelated with each other, but can be influenced differently by the 2011 earthquake. In fact, more than 400,000

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[16] However, differences in post-quake responses between large and small houses cannot be attributed solely to types of residents and their attitudes toward risk. For example, the expected length of residence tends to be long among properties intended for families, which may be connected to the size of influence of earthquake risk indexes.

buildings either totally or partially collapsed after the 2011 earthquake, most of which were caused by the catastrophic tsunami, whereas fire damages were relatively minor. Since devastating tsunami damage and the resulting building collapses are highly publicized by the media after the earthquake, changes in public perception towards building collapse risk can be greater than those in fire risk perception.

(Table 6 here)

Table 6 summarizes our regression results. Panel (a) presents regression results using building collapse risk instead of combined risk index. We find that these results are quite similar to our benchmark results presented in Table 2. For sales transactions, we could not find any significant pre-quake relationship between building collapse risk and house price. Post-quake changes, on the other hand, indicate that price discounts for properties located in high-risk areas become significantly larger after the earthquake for sales transactions. Quantitatively, post-quake changes are somewhat larger for building collapse risk than for combined risk presented in Table 2. For rental transactions, we find significant relationship in the pre-quake periods, but could not find significant changes in the relationship after the earthquake.

Panel (b) presents regression results using fire risk index. For pre-quake periods, we find significant relationship between fire risk and housing prices for rental transactions but not for sales transactions. These results are consistent with the notion that sales properties tend to have higher quality, and are thus more fire resistant than rental houses. For post-quake periods, we do not find any significant changes in the relationship between fire risk and housing prices/rents, regardless of the transaction types (sales or rental).

Overall, empirical results from Table 6 suggest that the 2011 earthquake could change the public perception of building collapse risk but not of fire risk, and confirm our benchmark results that changes in risk perception are found for prospective homebuyers, rather than for tenants.

4.4 Time-Varying Effects after the Earthquake

In this section, we examine time-varying post-quake effects of earthquake risk on housing price. Specifically, we extend the sample period after the earthquake to the recent present, September 2017, and conduct an analysis introducing an interaction term with a post-quake year dummies and earthquake risk index. Figure 3 summarizes estimated coefficients for years after the 2011 earthquake.[17]

(Figure 3 here)

Panel (a) shows results for sales transactions. Average prices for properties located in high-risk areas becomes lower than their pre-quake baseline for several years after the earthquake, but after that price levels return to their pre-quake baseline (relative to those in safest areas). A similar pattern can be observed for average prices for properties located in medium-risk areas, but the coefficient estimates are much smaller and are less precisely estimated than those for high-risk areas. Panel (b) shows results for rental transactions. Consistent with our benchmark results in Table 2, we could not find significant changes in rent discounts after the earthquake for rental

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[17] The original regression results are presented in Appendix Table A1. Estimated coefficient values presented in Figure 3 are based on models with CCM fixed effects.

properties.

Overall, we find that price discounts for sales properties in risky areas can be observed for three to five years after the earthquake, but they are diminishing over time. These results are consistent with findings in Kawawaki (2007), who verified subjective changes in risk awareness after an earthquake using areas affected by the Great Hanshin–Awaji Earthquake. A similar pattern is found in Atreya et al. (2013) showing that house prices in floodplain zones are substantially decreased for several years after actual flooding.

5 Conclusion

In this study, we used real estate property data covering a period both before and after the Great East Japan Earthquake to investigate whether large-scale disaster can change people's risk perception towards potential disasters in unaffected areas.

Our findings are summarized as follows. First, after the 2011 earthquake, significant price discounts in risky areas are observed for sales transactions, but not for rental transactions. This suggests that changes in risk perception are found for prospective homebuyers, rather than for tenants. The empirical results using building collapse risk indexes and fire risk indexes further suggested that the above results are mainly attributable to changes in awareness of building collapse risk.

Second, changes in subjective risk after an earthquake possibly differ depending on the type of resident. Our results suggest that post-quake price discounts in risky areas are larger for three- or more bedroom houses than for one- or two-bedroom houses. This suggests that potential residents at these properties more greatly altered their subjective risk awareness.

Third, we found that post-quake price discounts were observed only for three to five years after the earthquake, and thereafter prices regressed to the baseline relationship seen prior to the earthquake.

Issues remaining after the conclusion of this study are as follows. First, in this study we made a comparison of before and after an earthquake, and verified changes in people's subjective awareness of disaster risk, but the specific factors that caused these changes remain to be discussed. Several past studies have indicated the possibility that disaster experiences themselves, including reporting on actual suffering and damage, may alter people's awareness of disaster risk. In fact, it may be that factors such as extensive media coverage on earthquake damage and direct earthquake damage alter awareness of disaster risk. On the other hand, there was a variety of earthquake information, including damage predictions publicized after the earthquake and speculation on the probability of a Tokyo inland earthquake, may have influenced people's awareness in the form of additional risk information. Thus, closely examining these possibilities, and understanding what factors influence people's awareness of disaster risk, may be a critical issue for disaster prevention policies.

Second, it may be possible to advance our essential understanding of the mechanism by which risk awareness is updated through more in-depth analysis of long-term changes following an earthquake. For example, Gallagher (2014) analyzed long-term changes in insurance enrollment rates after a flood event, and showed that enrollment temporarily rose after the disaster, and then returned to pre-occurrence levels. This may be considered similar to the results of this study. These results may be explained by a cognitive bias, such as an availability heuristic, in which information that is immediately available (once a disaster has occurred) may greatly influence people's disaster risk assessment, but recedes in influence over time (Tversky and Kahneman, 1974). On the other hand, an alternative explanation that may be considered is mid- to long-term population shifts and sorting, in which people more sensitive to risk move out of risky areas, while people who are not, move into the same area. This alternative explanation implies that different policies must be implemented after each disaster for effective prevention. Therefore, more detailed analysis accounting for population shifts and other data is required.

References

Atreya, A., S. Ferreira, and W. Kriesel (2013)," Forgetting the flood? An analysis of the flood risk discount over time," *Land Economics*, 89 (4), 577-596.

Bauer, T. K., S. T. Braun, and M. Kvasnicka (2017),"Nuclear power plant closures and local housing values: Evidence from Fukushima and the German housing market," *Journal of Urban Economics*, 99, 94-106.

Beron, K. J., J. C. Murdoch, M. A. Thayer, and W. P. M. Vijverberg (1997),"An analysis of the housing market before and after the 1989 Loma Prieta Earthquake," *Land Economics*, 73, 101-113.

Bin, O., and C. E. Landry (2013),"Changes in implicit flood risk premiums: Empirical evidence from the housing market," *Journal of Environmental Economics and Management*, 65 (3), 361-376.

Bin, O. and S. Polasky (2004),"Influence of flood hazards on property values: Evidence before and after Hurricane Floyd," *Land Economics*, 80 (4), 490-500.

Boes, S., S. Nüesch, and K. Wüthrich (2015),"Hedonic valuation of the perceived risks of nuclear power plants," *Economics Letters*, 133, 109-111.

Cameron, L., and M. Shah (2015), "Risk-taking behavior in the wake of natural disasters," *Journal of Human Resources*, 50 (2), 484-515.

Fink, A., and T. Stratmann (2015),"US housing prices and the Fukushima nuclear accident," *Journal of Economic Behavior and Organization*, 117, 309-326.

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

Gu, T., M. Nakagawa, M. Saito, and H. Yamaga (2018), "Public perceptions of earthquake risk and the impact on land pricing: The case of the Uemachi Fault line in Japan," *Japanese Economic Review*, 69 (4), 374-393.

Hanaoka, C., H. Shigeoka, and Y. Watanabe (2018), "Do risk preferences change? Evidence from the Great East Japan Earthquake," *American Economic Journal: Applied Economics*, 10 (2), 298-330.

Jiang, Y. Y., Y. Asai, and S. Moridaira (2013), “On household insurance demand and loss control: Evidence from the Great East Japan Earthquake,” *International Journal of Business*, 18 (4), 332-350.

Kask, S. B., and S. A. Maani (1992), “Uncertainty, information, and hedonic pricing,” *Land Economics*, 68 (2), 170-184.

Kawaguchi, D. and N. Yukutake (2017), “Estimating the residential land damage of the Fukushima nuclear accident,” *Journal of Urban Economics*, 99, 148-160.

Kousky, C. (2010), “Learning from extreme events: Risk perceptions after the flood,” *Land Economics*, 86 (3), 395-422.

Kousky, C. (2017), “Disasters as learning experiences or disasters as policy opportunities? Examining flood insurance purchases after hurricanes,” *Risk Analysis*, 37 (3), 517-530.

Kunreuther, H., and M. Pauly (2004), “Neglecting disaster: Why don’t people insure against large losses?,” *Journal of Risk and Uncertainty*, 28 (1), 5-21.

Lichtenstein, S., P. Slovic, B. Fischhoff, M. Layman, and B. Combs (1978), “Judged frequency of lethal events,” *Journal of Experimental Psychology: Human Learning and Memory*, 4 (6), 551-578.

Lo, A. Y., and L. T. O. Cheung (2015), “Seismic risk perception in the aftermath of Wenchuan earthquakes in southwestern China,” *Natural Hazards*, 78, 1979-1996.

Matsuura, H. and K. Sato (2018), “Economic evaluation of multi-hazard risk information in Japan: Implication for earthquake risk communication,” in Fletcher, C. V. and J. Lovejoy (eds.), *Natural Disasters and Risk Communication: Implications of the Cascadia Subduction Zone Megaquake*, Lexington Press.

Nakagawa, M., M. Saito, and H. Yamaga (2007), “Earthquake risk and housing rents: Evidence from the Tokyo Metropolitan Area,” *Regional Science and Urban Economics*, 37 (1), 87-99.

Nakagawa, M., M. Saito, & H. Yamaga (2009). Earthquake risks and land prices: Evidence from the Tokyo Metropolitan Area,” *Japanese Economic Review*, 60 (2), 208-222.

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

Naoi, M., M. Seko, and T. Ishino (2012), “Earthquake risk in Japan: Consumers’ risk mitigation responses after the Great East Japan earthquake,” *Journal of Economic Issues*, 46 (2), 519-530.

Rogers, G. O. (1997), “The dynamics of risk perception: How does perceived risk respond to risk events?,” *Risk Analysis*, 17 (6), 745-757.

Said, F., U. Afzal, and G. Turner (2015), “Risk taking and risk learning after a rare event: evidence from a field experiment in Pakistan,” *Journal of Economic Behavior and Organization*, 118, 167-183.

Tanaka, S., and J. Zabel (2018), “Valuing nuclear energy risk: Evidence from the impact of the Fukushima crisis on US house prices,” *Journal of Environmental Economics and Management*, 88, 411-426.

Tversky, A., and D. Kahneman (1974), “Judgment Under Uncertainty: Heuristics and Biases,” *Science*, 185 (4157), 1124-1131.

Viscusi, W. K. (1985), “A Bayesian perspective on biases in risk perception,” *Economics Letters*, 17 (1-2), 59-62.

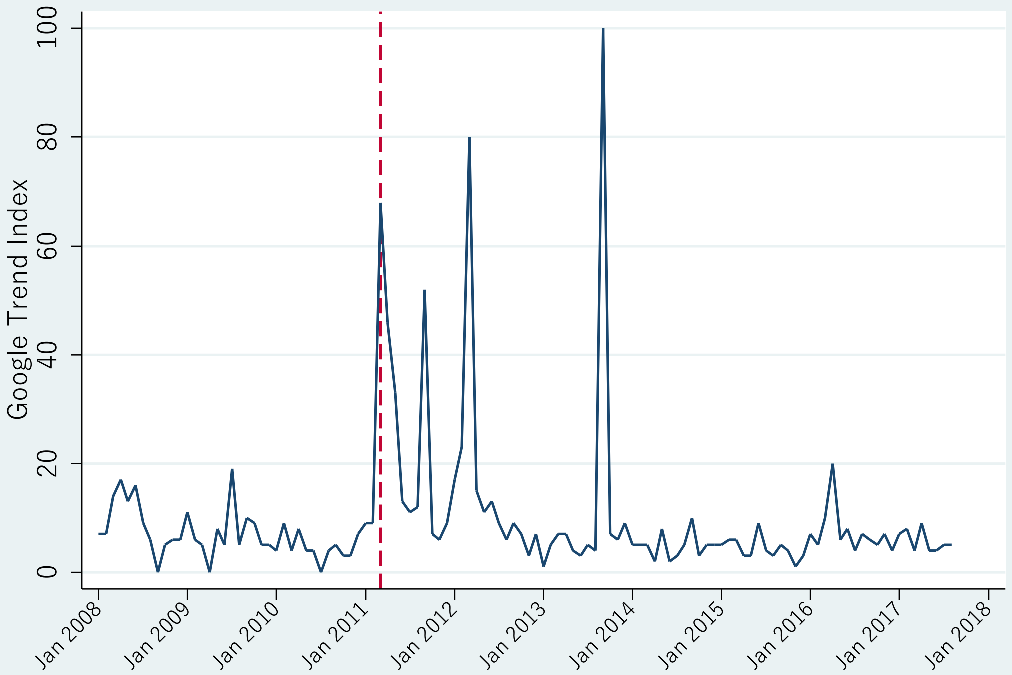
Zhu, H., Y. Deng, R. Zhu, and X. He (2016), “Fear of nuclear power? Evidence from Fukushima nuclear accident and land markets in China,” *Regional Science and Urban Economics*, 60, 139-154.

Ishizuka, H., Yokoi, T. (2017), “Influence of natural disaster risk information on land trading prices in the Tokyo metropolitan area before and after the Great East Japan Earthquake,” *Journal of Applied Regional Science*, No. 21, 1-16.

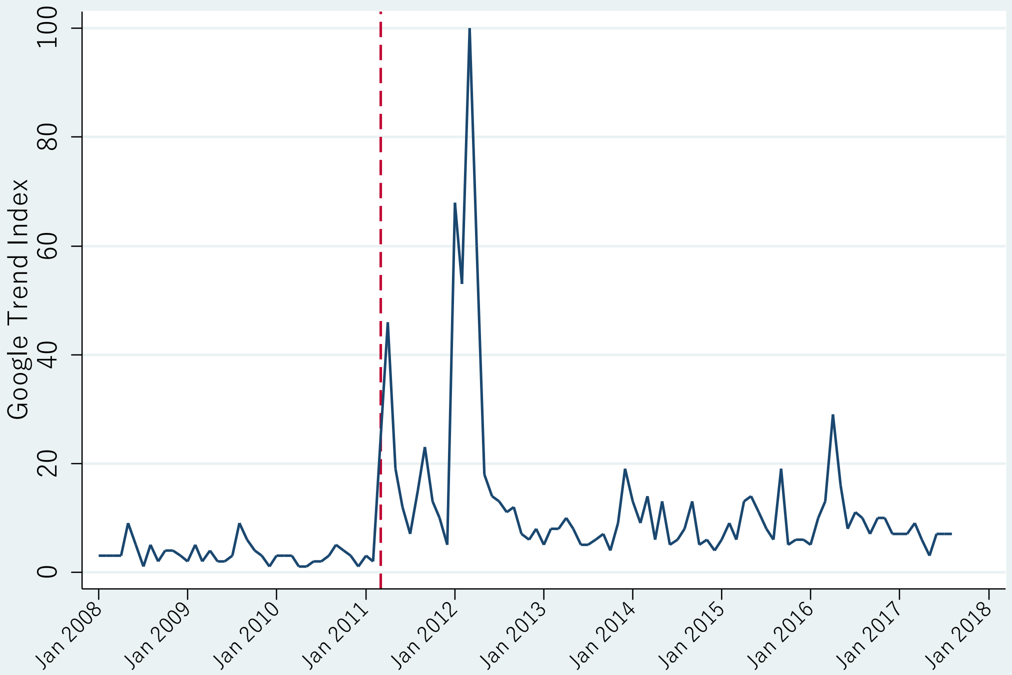
Kawawaki, Y. (2007), “Earthquake risk awareness bias and land prices: Verification of areas affected by the Great Hanshin-Awaji Earthquake,” The Japanese Journal of Real Estate Sciences, Vol. 21, No. 1, 104-115.

Fire and Disaster Management Agency (2017), “2017 White Paper on Fire Service,” Ministry of Finance Printing Works.

Figure 1: Google Trends for Earthquake Risk in Tokyo



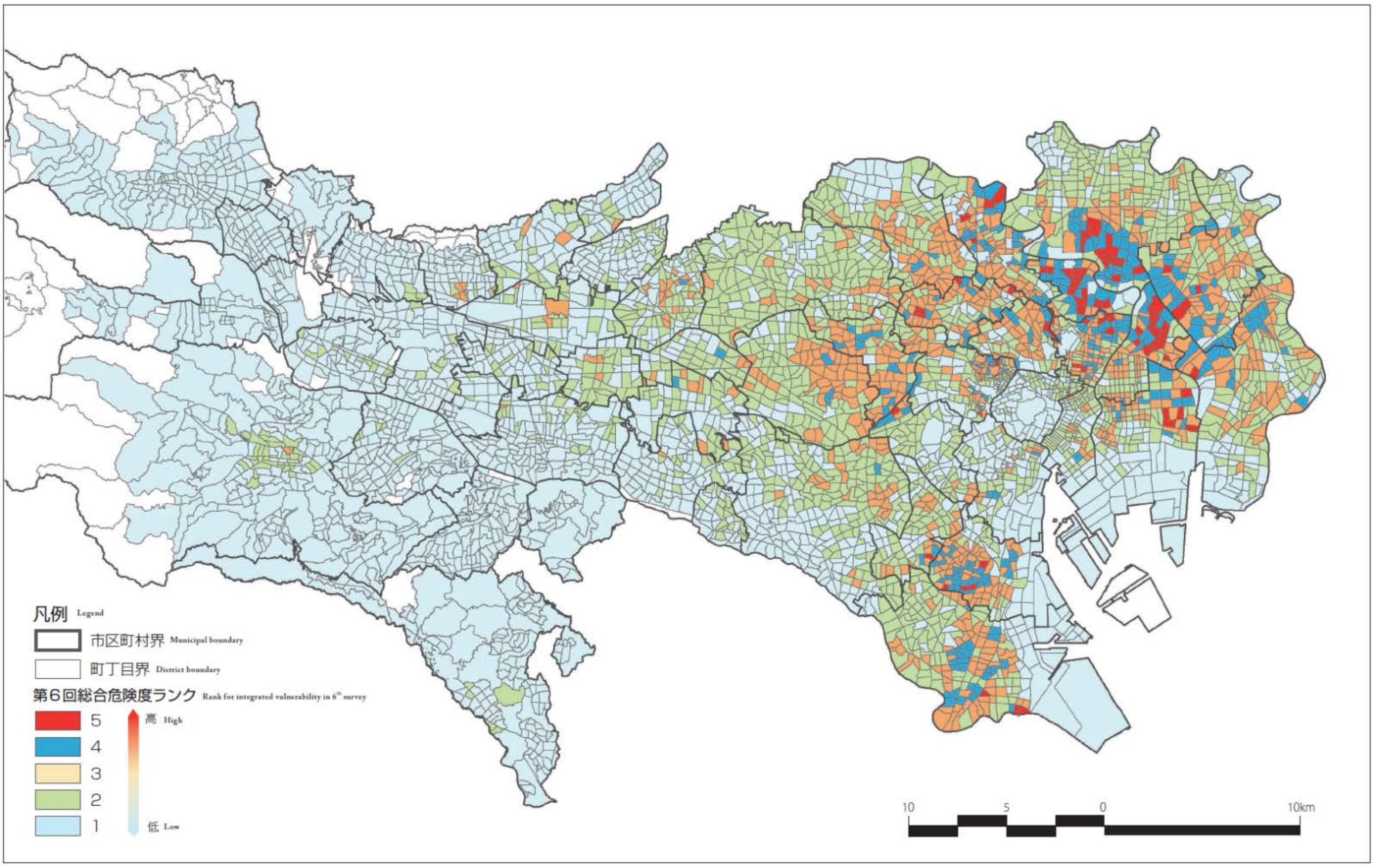
(a) "Earthquake Risk Index" (Jishin Kikendo)



(b) "Tokyo Inland Earthquake" (Shuto-Chokka-Jishin)

Notes: Search area is the Tokyo metropolitan area. Search period is January 2008 to August 2017. Search words are (a) “earthquake risk index” and (b) “Tokyo inland earthquake,” respectively.

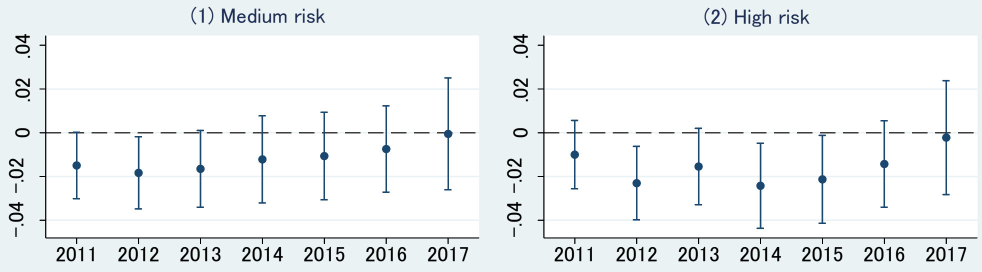
Figure 2: Geographic Distribution of Earthquake Risk Indexes in Tokyo



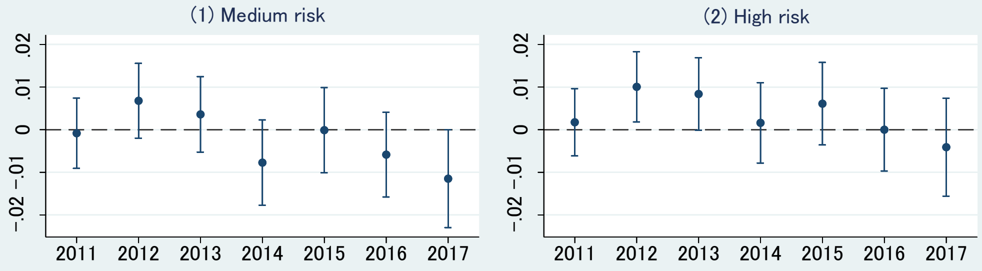
Source: “Survey of District-based Vulnerability to Earthquake Disaster” (Tokyo Metropolitan Government Bureau of Urban Development, 6th edition)

Figure 3: Time-Varying Effects After the Earthquake

(a) Sales Transactions



(b) Rental Transactions



Notes: Plot of estimated values of interaction term with per earthquake risk index dummy variable and post-earthquake yearly dummy variable. Based on estimation results accounting for fixed effects at the town and area level. Range in vertical solid lines indicates 95% confidence interval. See Appendix Table A1 for details of results.

Table 1: Summary Statistics

Variables	Sales Transaction						Rental Transactions					
	Full Sample		Pre-Quake		Post-Quake		Full Sample		Pre-Quake		Post-Quake	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Transaction price/rent (in 10,000 JPY/m^2)	3341.5	(2142.5)	3393.4	(2189.8)	3267.0	(2070.4)	10.7	(12.3)	11.2	(11.5)	10.1	(13.1)
Earthquake risk index												
Low risk (rank 1)	0.262	(0.440)	0.262	(0.440)	0.262	(0.440)	0.150	(0.357)	0.159	(0.366)	0.140	(0.347)
Medium risk (rank 2)	0.416	(0.493)	0.417	(0.493)	0.415	(0.493)	0.413	(0.492)	0.413	(0.492)	0.414	(0.493)
High risk (rank 3 to 5)	0.321	(0.467)	0.320	(0.467)	0.322	(0.467)	0.436	(0.496)	0.428	(0.495)	0.446	(0.497)
Age of building	16.71	(11.44)	16.00	(11.22)	17.72	(11.69)	16.22	(11.18)	15.35	(10.91)	17.18	(11.39)
Floor space (m^2)	59.75	(22.78)	59.94	(22.57)	59.47	(23.08)	34.92	(137.10)	35.28	(27.94)	34.51	(196.59)
Floor level	6.28	(6.01)	6.22	(5.96)	6.36	(6.08)	3.93	(3.40)	4.02	(3.55)	3.82	(3.21)
Distance to CBD (km)	5.09	(3.05)	5.12	(3.07)	5.04	(3.02)	4.81	(3.08)	4.66	(3.02)	4.98	(3.13)
N	53,181		31,334		21,847		268,743		140,890		127,853	

Notes: “Pre-quake” denotes results for properties closed between March 11, 2009 and March 10, 2011, and “After earthquake” denotes the tally results for properties closed between March 11, 2011 and March 10, 2013.

Table 2: House Prices and Earthquake Risk Index

Dependent variable: log(Price/Rent)	Sales Transactions		Rental Transactions	
	[1]	[2]	[3]	[4]
Earthquake risk index (ERI) (Ref: Low risk)				
Medium risk (rank 2)	0.0212 *		-0.0201 ***	
	(0.0117)		(0.0069)	
High risk (rank 3 to 5)	0.0166		-0.0198 ***	
	(0.0111)		(0.0068)	
ERI × Post-quake dummy (Ref: Low risk)				
Medium risk (rank 2)	-0.0209 **	-0.0185 **	0.0052	0.0013
	(0.0084)	(0.0077)	(0.0048)	(0.0036)
High risk (rank 3 to 5)	-0.0196 **	-0.0192 **	0.0088 *	0.0038
	(0.0084)	(0.0078)	(0.0047)	(0.0035)
Post-quake dummy	-0.0272 ***	-0.0262 ***	-0.0038	0.0000
	(0.0082)	(0.0073)	(0.0047)	(0.0035)
Property characteristics				
log(Floor space)	1.1329 ***	1.1176 ***	0.7380 ***	0.7284 ***
	(0.0051)	(0.0036)	(0.0049)	(0.0043)
log(Age of building)	-0.2554 ***	-0.2612 ***	-0.0487 ***	-0.0487 ***
	(0.0045)	(0.0042)	(0.0009)	(0.0009)
log(Floor level)	0.0434 ***	0.0503 ***	0.0504 ***	0.0468 ***
	(0.0045)	(0.0018)	(0.0018)	(0.0014)
log(Distance to CBD)	-0.1229 ***		-0.0864 ***	
	(0.0105)		(0.0054)	
Fixed effects	District	CCM	District	CCM
R^2	0.9036	0.9359	0.8615	0.8877
N	53,181	53,181	268,743	268,743

Notes: ***, **, and * indicate that estimated coefficients are statistically significant at a 1%, 5%, and 10% levels, respectively. Cluster-robust standard errors are in the parentheses. Building structure dummies (wooden frame, block, steel frame, RC, SRC, PC, HPC, LGS, and others), and district×year and district×month fixed effects are also controlled for but omitted from the table.

Table 3: Hedonic Results by the Quake-Resistance Standards

Dependent variable: log(Price/Rent)	Sales Transactions				Rental Transactions			
	[1]		[2]		[3]		[4]	
	Old std.	New std.	Old std.	New std.	Old std.	New std.	Old std.	New std.
Earthquake risk index (ERI) (Ref: Low risk)								
Medium risk (rank 2)	-0.0240 *	0.0240 **			-0.0060	-0.0252 ***		
	(0.0141)	(0.0122)			(0.0102)	(0.0073)		
High risk (rank 3 to 5)	-0.0342 **	0.0139			-0.0055	-0.0261 ***		
	(0.0166)	(0.0115)			(0.0104)	(0.0072)		
ERI × Post-quake dummy (Ref: Low risk)								
Medium risk (rank 2)	-0.0088	-0.0230 ***	-0.0003	-0.0214 ***	0.0136	0.0035	0.0110	-0.0021
	(0.0135)	(0.0081)	(0.0142)	(0.0069)	(0.0090)	(0.0052)	(0.0069)	(0.0036)
High risk (rank 3 to 5)	-0.0130	-0.0244 ***	0.0020	-0.0221 ***	0.0109	0.0081	0.0103	0.0013
	(0.0167)	(0.0081)	(0.0170)	(0.0069)	(0.0088)	(0.0051)	(0.0068)	(0.0035)
Post-quake dummy	-0.0455 **	-0.0192 **	-0.0572 ***	-0.0173 ***	-0.0109	-0.0016	-0.0098	0.0043
	(0.0192)	(0.0079)	(0.0206)	(0.0064)	(0.0097)	(0.0051)	(0.0085)	(0.0035)
Fixed effects	District		CCM		District		CCM	
R^2	0.8426	0.9142	0.8905	0.9509	0.8129	0.8737	0.8609	0.9012
N	9,905	43,276	9,905	43,276	34,780	233,963	34,780	233,963

Notes: ***, **, and * indicate that estimated coefficients are statistically significant at a 1%, 5%, and 10% levels, respectively. Cluster-robust standard errors are in the parentheses. Housing characteristics (floor space, age, floor level, and distance to CBD), building structure dummies (wooden frame, block, steel frame, RC, SRC, PC, HPC, LGS, and others), and district×year and district×month fixed effects are also controlled for but omitted from the table.

Table 4: Hedonic Results by the Number of Bedrooms

Dependent variable: log(Price/Rent)	Sales Transactions				Rental Transactions			
	[1]		[2]		[3]		[4]	
	1-2 rooms	3 rooms+	1-2 rooms	3 rooms+	1-2 rooms	3 rooms+	1-2 rooms	3 rooms+
Earthquake Risk Index (Ref: Rank 1)								
Rank 2	0.0307 **	0.0029			-0.0177 ***	-0.0153		
	(0.0130)	(0.0120)			(0.0067)	(0.0104)		
Rank 3 to 5	0.0280 **	-0.0048			-0.0184 ***	-0.0145		
	(0.0123)	(0.0123)			(0.0066)	(0.0107)		
ERI × Post-quake dummy (Ref: Rank 1)								
Rank 2	-0.0210 **	-0.0148 *	-0.0131	-0.0231 ***	0.0042	0.0122	0.0006	-0.0031
	(0.0104)	(0.0086)	(0.0099)	(0.0078)	(0.0049)	(0.0101)	(0.0036)	(0.0074)
Rank 3 to 5	-0.0208 **	-0.0123	-0.0151	-0.0252 ***	0.0080 *	0.0144	0.0034	-0.0037
	(0.0105)	(0.0098)	(0.0101)	(0.0094)	(0.0047)	(0.0110)	(0.0035)	(0.0083)
Post-quake dummy	-0.0363 ***	-0.0149	-0.0392 ***	-0.0055	-0.0041	-0.0003	-0.0001	0.0063
	(0.0105)	(0.0106)	(0.0098)	(0.0093)	(0.0047)	(0.0128)	(0.0036)	(0.0101)
Fixed effects	District		CCM		District		CCM	
R^2	0.9079	0.8519	0.9371	0.9127	0.8445	0.8849	0.8720	0.9282
N	32,796	20,385	32,796	20,385	251,101	17,642	251,101	17,642

Notes: ***, **, and * indicate that estimated coefficients are statistically significant at a 1%, 5%, and 10% levels, respectively. Cluster-robust standard errors are in the parentheses. Housing characteristics (floor space, age, floor level, and distance to CBD), building structure dummies (wooden frame, block, steel frame, RC, SRC, PC, HPC, LGS, and others), and district×year and district×month fixed effects are also controlled for but omitted from the table.

Table 5: Hedonic Results by Floor Levels

Dependent variable: log(Price/Rent)	Sales Transactions				Rental Transactions			
	[1]		[2]		[3]		[4]	
	Fifth floor-	Sixth floor+	Fifth floor-	Sixth floor+	Fifth floor-	Sixth floor+	Fifth floor-	Sixth floor+
Earthquake Risk Index (Ref: Rank 1)								
Rank 2	-0.0030	0.0574 ***			-0.0199 ***	-0.0068		
	(0.0098)	(0.0164)			(0.0065)	(0.0108)		
Rank 3 to 5	-0.0094	0.0529 ***			-0.0186 ***	-0.0105		
	(0.0099)	(0.0149)			(0.0066)	(0.0100)		
ERI × Post-quake dummy (Ref: Rank 1)								
Rank 2	-0.0090	-0.0354 ***	-0.0059	-0.0331 ***	0.0064	0.0025	0.0023	-0.0011
	(0.0080)	(0.0132)	(0.0072)	(0.0121)	(0.0048)	(0.0078)	(0.0037)	(0.0064)
Rank 3 to 5	-0.0059	-0.0348 ***	-0.0037	-0.0362 ***	0.0092 *	0.0080	0.0038	0.0058
	(0.0088)	(0.0124)	(0.0083)	(0.0113)	(0.0048)	(0.0076)	(0.0037)	(0.0061)
Post-quake dummy	-0.0340 ***	-0.0174	-0.0323 ***	-0.0181 *	-0.0060	0.0017	-0.0010	0.0027
	(0.0096)	(0.0121)	(0.0088)	(0.0103)	(0.0047)	(0.0083)	(0.0037)	(0.0071)
Fixed effects	District		CCM		District		CCM	
R^2	0.9077	0.8941	0.9355	0.9375	0.8415	0.8914	0.8698	0.9228
N	31,430	21,751	31,430	21,751	217,908	50,835	217,908	50,835

Notes: ***, **, and * indicate that estimated coefficients are statistically significant at a 1%, 5%, and 10% levels, respectively. Cluster-robust standard errors are in the parentheses. Housing characteristics (floor space, age, floor level, and distance to CBD), building structure dummies (wooden frame, block, steel frame, RC, SRC, PC, HPC, LGS, and others), and district×year and district×month fixed effects are also controlled for but omitted from the table.

Table 6: Hedonic Results Using Alternative Risk Measures

Dependent variable: log(Price/Rent)	Sales Transactions		Rental Transactions	
	[1]	[2]	[3]	[4]
(a) Building Collapse Risk				
Building Collapse Risk Index (BCRI) (Ref: Low risk)				
Medium risk (rank 2)	0.0186 *		-0.0191 ***	
	(0.0112)		(0.0066)	
High risk (rank 3 to 5)	0.0191		-0.0294 ***	
	(0.0123)		(0.0069)	
BCRI × Post-quake dummy (Ref: Low risk)				
Medium risk (rank 2)	-0.0241 ***	-0.0206 ***	0.0067	0.0014
	(0.0080)	(0.0073)	(0.0047)	(0.0034)
High risk (rank 3 to 5)	-0.0265 ***	-0.0236 ***	0.0119 **	0.0077 **
	(0.0092)	(0.0086)	(0.0049)	(0.0035)
Post-quake dummy	-0.0241 ***	-0.0243 ***	-0.0055	-0.0012
	(0.0080)	(0.0071)	(0.0046)	(0.0034)
Fixed effects	District	CCM	District	CCM
R^2	0.9036	0.9359	0.8616	0.8877
N	53,181	53,181	268,743	268,743
(b) Fire Risk				
Fire Risk Index (FRI) (Ref: Low risk)				
Medium risk (rank 2)	0.0158		-0.0125 *	
	(0.0111)		(0.0066)	
High risk (rank 3 to 5)	0.0039		-0.0155 **	
	(0.0106)		(0.0065)	
FRI × Post-quake dummy (Ref: Low risk)				
Medium risk (rank 2)	-0.0062	-0.0104	0.0028	0.0001
	(0.0077)	(0.0071)	(0.0049)	(0.0035)
High risk (rank 3 to 5)	-0.0111	-0.0108	0.0067	0.0018
	(0.0078)	(0.0073)	(0.0047)	(0.0033)
Post-quake dummy	-0.0359 ***	-0.0323 ***	-0.0018	0.0014
	(0.0077)	(0.0068)	(0.0046)	(0.0034)
Fixed effects	District	CCM	District	CCM
R^2	0.9036	0.9359	0.8614	0.8877
N	53,181	53,181	268,743	268,743

Notes: ***, **, and * indicate that estimated coefficients are statistically significant at a 1%, 5%, and 10% levels, respectively. Cluster-robust standard errors are in the parentheses. Housing characteristics (floor space, age, floor level, and distance to CBD), building structure dummies (wooden frame, block, steel frame, RC, SRC, PC, HPC, LGS, and others), and district×year and district×month fixed effects are also controlled for but omitted from the table.

Table A1: Time-Varying Treatment Effects After the Earthquake

Dependent variable: log(Price/Rent)	Sales Transactions		Rental Transactions	
	[1]	[2]	[3]	[4]
Earthquake Risk Index (Ref: Rank 1)				
Rank 2	0.0183	0.0063	-0.0220 ***	-0.0067
	(0.0120)	(0.0101)	(0.0070)	(0.0059)
Rank 3 to 5	0.0131	0.0034	-0.0223 ***	-0.0082
	(0.0114)	(0.0116)	(0.0069)	(0.0063)
ERI × Year dummies (Ref: Rank 1)				
Rank 2				
Year = 2011	-0.0214 **	-0.0149 *	-0.0015	-0.0008
	(0.0090)	(0.0077)	(0.0051)	(0.0042)
Year = 2012	-0.0199 **	-0.0183 **	0.0129 **	0.0068
	(0.0096)	(0.0084)	(0.0060)	(0.0045)
Year = 2013	-0.0190 *	-0.0165 *	0.0062	0.0036
	(0.0104)	(0.0089)	(0.0062)	(0.0045)
Year = 2014	-0.0165	-0.0122	-0.0087	-0.0077
	(0.0115)	(0.0102)	(0.0070)	(0.0051)
Year = 2015	-0.0218 *	-0.0107	0.0077	-0.0001
	(0.0125)	(0.0102)	(0.0067)	(0.0051)
Year = 2016	-0.0038	-0.0074	0.0024	-0.0059
	(0.0131)	(0.0100)	(0.0070)	(0.0051)
Year = 2017	0.0030	-0.0005	-0.0070	-0.0115 **
	(0.0169)	(0.0130)	(0.0080)	(0.0059)
Rank 3 to 5				
Year = 2011	-0.0141	-0.0100	0.0031	0.0017
	(0.0091)	(0.0080)	(0.0050)	(0.0040)
Year = 2012	-0.0269 ***	-0.0230 ***	0.0164 ***	0.0101 **
	(0.0097)	(0.0086)	(0.0058)	(0.0042)
Year = 2013	-0.0237 **	-0.0154 *	0.0098	0.0084 *
	(0.0102)	(0.0089)	(0.0060)	(0.0043)
Year = 2014	-0.0393 ***	-0.0242 **	-0.0036	0.0016
	(0.0113)	(0.0099)	(0.0068)	(0.0048)
Year = 2015	-0.0413 ***	-0.0213 **	0.0073	0.0061
	(0.0124)	(0.0102)	(0.0066)	(0.0049)
Year = 2016	-0.0209	-0.0143	0.0001	0.0000
	(0.0130)	(0.0101)	(0.0071)	(0.0049)
Year = 2017	-0.0057	-0.0022	-0.0082	-0.0041
	(0.0174)	(0.0133)	(0.0083)	(0.0059)
Fixed effects	District	CCM	District	CCM
R^2	0.9037	0.9352	0.8453	0.8731
N	117,057	117,057	600,704	600,704

Notes: ***, **, and * indicate that estimated coefficients are statistically significant at a 1%, 5%, and 10% levels, respectively. Cluster-robust standard errors are in the parentheses. Housing characteristics (floor space, age, floor level, and distance to CBD), building structure dummies (wooden frame, block, steel frame, RC, SRC, PC, HPC, LGS, and others), and district×year and district×month fixed effects are also controlled for but omitted from the table.