KEIO UNIVERSITY
MARKET QUALITY RESEARCH PROJECT
(A 21st Century Center of Excellence Project)

KUMQRP DISCUSSION PAPER SERIES

DP2007-004

Effects of Earthquake Occurrence Probability on Housing Prices in Japan: Estimation of the Earthquake Risk Premium

Michio Naoi *
Kazuto Sumita **
Miki Seko ***

Abstract

The relationship between seismic risk and rental and owner-occupied housing prices in Japan are examined. Empirical results from hedonic regressions with earthquake risk indices suggest that (1) the earthquake occurrence probability has significantly negative effect on the monthly housing rent, (2) the effect of earthquake probability seems to depend on the characteristics of the individual housing unit (e.g. age of dwelling) for owner-occupied housing, (3) the estimated risk premium is much larger for older buildings, and (4) the share of quake-resistant dwellings in the neighborhood area is significantly and positively related to the housing price of the individual unit. These results suggest that anti-seismic policies targeting specific groups of dwellings — such as rental houses and older buildings — help to mitigate the welfare loss due to the earthquake loss.

JEL classification: R10, C23.
Keywords: Earthquake, Hedonic price model, Risk premium.

* Assistant Professor, Faculty of Business and Commerce, Keio University
** Full-time lecturer, Department of Economics, Kanazawa Seiryo University
*** Professor, Faculty of Economics, Keio University

Graduate School of Economics and Graduate School of Business and Commerce, Keio University
2-15-45 Mita, Minato-ku, Tokyo 108-8345, Japan

Effects of Earthquake Occurrence Probability on Housing Prices in Japan: Estimation of the Earthquake Risk Premium*

July 19, 2007

Michio Naoi[a,†], Kazuto Sumita[b], Miki Seko[c]

a. Faculty of Business and Commerce, Keio University, Mita Toho Bldg. 5th Floor, 3-1-7 Mita, Minato-ku, Tokyo, 108-0073, Japan

b. Department of Economics, Kanazawa Seiryo University, Ushi 10-1, Gosho-machi, Kanazawa-shi, Ishikawa, 920-8620, Japan

c. Faculty of Economics, Keio University, 2-15-45 Mita, Minato-ku, Tokyo, 108-8345, Japan

Abstract

The relationships between seismic risk and rental and owner-occupied housing prices in Japan are examined. Empirical results from hedonic regressions with earthquake risk indices suggest that (1) the earthquake occurrence probability has significantly negative effect on the monthly housing rent, (2) the effect of earthquake probability seems to depend on the characteristics of the individual housing unit (e.g. age of dwelling) for owner-occupied housing, (3) the estimated risk premium is much larger for older buildings, and (4) the share of quake-resistant dwellings in the neighborhood area is significantly and positively related to the housing price of the individual unit. These results suggest that anti-seismic policies targeting specific groups of dwellings — such as rental houses and older buildings — help to mitigate the welfare loss due to the earthquake loss.

JEL classification: R10, C23.

Keywords: Earthquake, Hedonic price model, Risk premium.

† Corresponding Author. *E-mail address:* naoi@2001.jukuin.keio.ac.jp

* Paper presented at the 12th Asian Real Estate Society Annual Conference, Macau, China, July 9–13, 2007. We are grateful to the National Research Institute for Earth Science and Disaster Prevention (NIED) for generously providing us with the data on earthquake occurrence probability. Financial support from the Japan Economic Research Foundation is gratefully acknowledged. The first author (Michio Naoi) acknowledges a Grant-in-Aid (#19730183) for Young Scientists from the Ministry of Education, Culture, Sports, Science and Technology. The second and third authors (Kazuto Sumita and Miki Seko) acknowledge a Grant-in-Aid (#19530157) for Scientific Research (C) from the Ministry of Education Culture, Sports, Science and Technology.

1 Introduction

As is well known, Japan is one of the world's most earthquake-prone countries since it lies at the junction of four tectonic plates. According to the Opinion Survey on Disaster Prevention (Jiji Press, 2002), earthquake (73.2%) is thought to be the most important risk factor among major natural and human disasters such as blaze (66.1%), flood (43.2%), and volcano eruption (15.7%).

Since earthquake is exogenous risk factor which is tied to specific location, its risk premium should be capitalized into local housing and land prices. Estimating earthquake risk premium is important not only because it is the direct measure for the welfare loss due to earthquake, but also because it is necessary for evaluating the effectiveness of the anti-disaster policies.

Earthquake risk should be divided into two components; (1) exogenous occurrence probability, and (2) local attributes which amplifies the damage of earthquake. Since earthquake probability is purely exogenous and is not under the policymaker's control, any policy instruments for disaster prevention should aim at minimizing earthquake damage. Since these two components are interrelated, i.e., anti-seismic policies may be extensively implemented in the region with high occurrence probability, omitting either of these components leads to incorrect result. For example, if we use occurrence probability as the index of earthquake risk, while omitting local attributes from the analysis, the impact of occurrence probability will be underestimated because anti-seismic policies are intensively implemented in the region with high occurrence probability. Therefore, we need to consider both of these components to assess the effectiveness of the anti-seismic policies by using observational data.

In this paper, we combine the household longitudinal data covering all Japan with seismic hazard information to estimate individuals' valuation of the earthquake risk. Compared with previous studies, our contribution is as follows. First, we explicitly introduce several measures of earthquake risk into our analysis and distinguish their effects. As noted above, exogenous earthquake occurrence probability and damage-amplifying local attributes are used as the separate measures of earthquake risk. Second, compared with previous studies that focus on fairly small areas, we use nation-wide longitudinal data in our analysis, allowing us to examine the entire effect of earthquake risk on the housing market in Japan. Thirdly, while previous studies mainly focus on land and rental market, our dataset allows us to study much wider range of housing market in Japan. It provides detailed price information for both rental and owner-occupied housing: monthly rent, assessed values for property taxes and owner-provided values of owner-occupied housing.

Our empirical findings are as follows. (1) The earthquake occurrence probability has significantly negative effect on the monthly housing rent. (2) The effect in the owner-occupied housing market is not so clear as in the rental market; however, the effect seems to depend on the characteristics of the individual housing unit (e.g. age of dwelling). (3) The estimated risk premium is much larger for older buildings. (4) The share of quake-resistant dwellings in the neighborhood area is significantly and positively related to the housing price of the individual unit.

The paper is organized as follows. Section 2 briefly reviews the previous studies of earthquake risk in the housing market. Section 3 introduces the data used (Keio Household Panel Survey, KHPS) and explains the estimation method and variables. Section 4 presents empirical results and interpretation. Section 5 summarizes the paper and presents some conclusions.

2 Previous Studies

In spite of its importance in the disaster prevention policies, there have been only limited studies of the effect of earthquake risk on housing and land prices. Among others, Willis and Asgary (1997) evaluate the cost and benefit of the anti-seismic policies by Contingent Valuation Method (CVM). Beron, Murdoch, Thayer, and Vijverberg (1997), introducing earthquake hazard indices as additional source of variation, conduct the hedonic analysis of the residential housing prices in the San Francisco Bay area, and compare the estimated hedonic functions before and after the 1989 Loma Prieta Earthquake. The result indicates that the hazard indices have significantly negative impact on the housing prices in both time periods; however, its impact is greater in pre-earthquake period, implying that the earthquake risk premium is overestimated before the Loma Prieta Earthquake occurred. Brookshire, Thayer, Tschirhart, and Schulze (1985) examine the effects of the disclosure of a hazard map in California on the land prices. It is found that the earthquake hazard indices have significantly negative impact after the disclosure, but not before it.

The studies most closely related to ours in the motivation are that by Nakagawa, Saito, and Yamaga (2007a, 2007b). While the former examines the impact on land market, the latter focuses on the rental market. Nakagawa et al. (2007a) empirically investigate the effect of earthquake risk on land prices using earthquake risk index taken from earthquake hazard map compiled by the Tokyo Metropolitan Government. Their result suggests that higher earthquake risk is certainly related with lower land prices in each area.

Nakagawa et al. (2007b) examine the impact of earthquake risk on housing rents in the Tokyo Metropolitan Area with special reference to the new Building Standard Law enacted in 1981, using the same earthquake risk index as used by Nakagawa et al. (2007a). They find that housing rents are substantially lower in the areas with exposure to higher earthquake risk. Also, it is found that the rent of houses built prior to 1981 is discounted more substantially in risky areas than that of houses built after 1981. The important point to be noted is their use of list prices of housing rent rather than the actual rent paid. Although using list prices of housing rent has several advantages, it must suffer from asymmetric information in housing market, i.e., the seller has better information on earthquake-resident quality of the unit than the buyer has, which might leads to the biased estimates of earthquake risk premium.

3 Data and Methodology

3.1 Data

The Keio Household Panel Survey (KHPS), sponsored by the Ministry of Education, Culture, Sports, Science and Technology, is the first comprehensive panel survey of households in Japan, conducted annually by Keio University since 2004. In wave 1, self-administered questionnaires were given to 4,005 respondents, male and female, aged 20-69 years. These respondents were selected by stratified two-stage random sampling. If the primary respondent was married at the time of the survey, the same questionnaire was given to his/her spouse. The standard procedure for the KHPS was to send a pre-survey letter to the respondent and then provide a post-interview payment of 3,000 yen (approximately $25) per household.

In the following analysis, three waves of the KHPS (2004–2006) are utilized to examine the relationship between seismic risk and housing prices in Japan, and to estimate the risk premium indices. As mentioned, various measures of housing prices are documented in the KHPS: For rental households, actual monthly rent paid is documented. For homeowners, assessed values for property taxes and owner-provided values of owner-occupied housing are documented.[1] The KHPS also provides detailed information on the type of housing – ownership status (owned, private rental, or public rental) and construction type (wooden or reinforced concrete building). Since risk premium might critically depends on housing types, these information are necessary for evaluating sole impact of seismic risk on the housing market, which are impossible in the previous studies due to data limitation.

The seismic risk measure is taken from the Probabilistic Seismic Hazard Map (PSHM) provided by the National Research Institute for Earth Science and Disaster Prevention (NIED).[2] The PSHM provides the probability of earthquake occurrence for a fixed time period and intensity. In the following analysis, we use the occurrence probability of earthquakes with ground motions equal to or larger than JMA seismic intensity 6^{-} within 30 years, as our measure of seismic risk. The Japan Meteorological Agency (JMA) seismic intensity scale, graded from 0 to 7, provides a measure of the strength of seismic motion.[3] The example of PSHM is shown in Figure 1.

(Figure 1 around here)

Since the unit of observation in the original PSHM is defined based on the 3rd level mesh codes (1km meshed grid), city-level averages are calculated in order to match the seismic risk measure with the KHPS.[4] The resulting seismic risk measures are quite heterogeneous across prefectures; there are remarkably high earthquake probabilities at the southern coastal region (Figure 2). Moreover, these measures are highly diversified even within the same prefecture. Therefore, the

---

[1] The latter measure of housing price is constructed from the answer to the question about subjective assessment of the value of current residence ("How much do you think this lot/house would sell for on today's market?").

[2] The original data is available at http://www.j-shis.bosai.go.jp/.

[3] The JMA seismic intensity scale, which is measured with a seismic intensity meter, provides a measure of the strength of seismic motion. The typical situations and damages caused by the earthquake with JMA seismic intensity 6^{-} are as follows: People are difficult to keep standing, wooden houses occasionally collapse, and walls and pillars may be damaged even for highly earthquake-resistant houses. For full explanation of the JMA seismic intensity scale, see http://www.jma.go.jp/jma/kishou/know/shindo/explane.html.

[4] This is because, in the KHPS, the information about the respondent's location of residence is reported at the city/county-levels. The city-level averages of earthquake occurrence probabilities are calculated by ArcView 9.0.

seismic risk should be treated as local attribute that is specific to fairly small area (i.e. cities).

(Figure 2 around here)

While the household's perception toward the seismic risk directly depends on the occurrence probabilities discussed above, it is also affected by the neighborhood characteristics of household's residential region. Once earthquake occurs, regions in which low quake-resistant dwellings are concentrated would suffer from immense damage. The city-level dwelling composition by its construction type is introduced to account for possible (negative) externalities. The data comes from the *2003 Housing and Land Survey of Japan* (Ministry of Land, Infrastructure and Transport, MLIT), which gives the fraction of dwellings with specific construction material — wooden, fire-proofed wooden, reinforced steel-framed concrete, and steel-framed dwellings — for every cities in Japan. Generally, wooden dwellings are thought to have least quake-resistant quality. Regions crowded with these dwellings will have higher earthquake risk not only because wooden buildings are easily collapsed but also these building will be major cause of the fire after the earthquake.

3.2 Empirical Model and Variables

Our primary interest is on estimating the seismic risk premium. The hedonic regression model is given as follows:

$$p_i^{(\lambda)} = \alpha + \beta EQ_i + x_i\gamma + \epsilon_i \tag{1}$$

where p_i is the appropriate housing price measure for unit i (it will be actual rent, assessed values for property taxes or owner-provided house values, depending on the model to be estimated), EQ_i is the seismic risk measure (i.e. earthquake probability), x_i is the relevant set of explanatory variables, and $\alpha, \beta,$ and γ are parameters to be estimated. The Box-Cox transformation with parameter λ yields

$$p_i^{(\lambda)} = \frac{p_i^{\lambda} - 1}{\lambda}. \tag{2}$$

The model becomes linear with $\lambda = 1$ and semi-logarithmic with $\lambda = 0$ as the special case. Following the previous studies on hedonic analysis of housing market, x_i includes the basic housing characteristics such as number of rooms, floor and garden space, years since the unit was built, number of floors, and the time distance to the nearest station/bus stop. In addition to these basic characteristics, we also control dummies for construction type and ownership status of the dwelling, city size, and the region in which the unit is located. The definition and summary statistics of the variables are shown in Table 1.

(Table 1 around here)

Since it is well-known that the Wald statistics for the estimated coefficients of the right-hand-side variables are not invariant to changes in the scale of the transformed dependent variable (Spitzer, 1984; Davidson and MacKinnon, 1993), we instead perform and report the likelihood-ratio tests for each coefficient.

Given the estimated coefficients ($\hat{\alpha}, \hat{\beta}, \hat{\gamma}$, and $\hat{\lambda}$), fitted values and marginal effects are given as follows:

Fitted value: $$\hat{p}(EQ, x) = \int \left[\hat{\lambda}\left(\hat{\alpha} + \hat{\beta}EQ + x\hat{\gamma} + \epsilon\right) + 1\right]^{\frac{1}{\hat{\lambda}}} d\hat{F}(\epsilon), \tag{3}$$

Marginal Effect: $$\widehat{m}(EQ, x) = \hat{\beta} \int \left[\hat{\lambda}\left(\hat{\alpha} + \hat{\beta}EQ + x\hat{\gamma} + \epsilon\right) + 1\right]^{\frac{1-\hat{\lambda}}{\hat{\lambda}}} d\hat{F}(\epsilon), \tag{4}$$

Where $\hat{F}$ is an estimate of the true error distribution F. Following Abrebaya (2002), the ‘‘smearing’’ technique, which uses estimated residuals to approximate the error distribution, is used to obtain the estimates of $\hat{p}$ and $\widehat{m}$. In the following analysis, the marginal effect of earthquake probability is evaluated at sample mean, i.e. $\widehat{m}(\overline{EQ}, \bar{x})$. The earthquake risk premium is estimate by the changes in the fitted values of housing prices from the as-if situation (i.e. zero earthquake probability), $\hat{p}(\overline{EQ}, \bar{x}) - \hat{p}(0, \bar{x})$.

4 Empirical Results

In the following analyses, we split the sample into three groups based on the ownership status of the unit — rental houses, owner-occupied detached houses, and owner-occupied condominium units — and estimate equation (1) for each of these three groups.

4.1 Baseline Result

Our baseline result is shown in Table 2. Five models are estimated for housing rent (Model [1]), owner-provided values and assessed values for property taxes of detached houses (Models [2] and [3]), and those of condominium units (Models [4] and [5]). In the table, estimated coefficients and marginal effects of seismic risk indices, i.e., earthquake occurrence probability and neighborhood dwelling composition, are reported.[5]

(Table 2 around here)

The results indicate that earthquake occurrence probability has significantly negative effect on housing rents and assessed values of detached houses, but not on other housing price measures.

Negative estimated coefficient and marginal effect in housing rent model is consistent with previous studies (Naoi, Sumita, and Seko, 2007; Nakagawa et al., 2007b). Our index of the earthquake risk premium indicates that the change in earthquake probability from hypothetical riskless situation to the actual average level (i.e. $0 \rightarrow 0.150$) leads to 3,654 yen decrease in monthly rent, implying that earthquake risk premium accounts for approximately 6% of average monthly rent ($3{,}654/61{,}280 = 5.96\%$).[6]

As for detached houses (Models [2] and [3]), significantly negative coefficient of earthquake

[5] A set of dwelling characteristics and dummy variables for regions and survey years is also controlled but is omitted from the results. Dwelling characteristics included are as follows: age of the dwelling (years since built), number of rooms, number of stories of the building, time-distance from the nearest railway station/bus stop, garden space (for detached houses), floor in which the room is located (for condominium units), and dummies for the type of dwelling. The complete results are available upon request.

[6] Nakagawa et al. (2007b) report that the risk premium is about 3 – 6% of the housing value.

probability is estimated for assessed values for property taxes, while it is not significant for (owner's estimates of) house values. This discrepancy will be further investigated in later sections. The earthquake risk premium index for Model [3] becomes roughly two million yen[7], about 14.5% of the average house value.

The results for condominium units (Models [4] and [5]) suggest that the earthquake probability does not have any significant impact on the pricing of these units. Unfortunately, this can be partly attributed to the limited sample sizes. Because these units are concentrated in urban areas, perhaps regional earthquake occurrence probability does not have enough variation to estimate its true effect. Therefore, although the effects are estimated to be insignificant, further investigation might be required in future research.

As for the neighborhood dwelling composition, estimated coefficients become generally positive and are mostly significant. Since the wooden building is considered to have lower quake-resistance quality than other types of building, the result indicates that replacing wooden dwellings with other types of quake-resistant buildings leads to higher housing prices in each region.

4.2 Changes in Effect of Earthquake Risk over Time

Interaction terms of earthquake occurrence probability with survey year dummies are introduced taking account of the fact that its effect may vary over time. The results are summarized in Table 3.

(Table 3 around here)

The overall results are similar to those reported in Table 1. However, in Model [1], the effect of earthquake probability on housing rent substantially varies over time. The negative effect is largest in 2006 and smallest in 2005. Given that quality of typical housing is unchanged during our sample period, possible interpretation for this result can be the update of household's perception toward the seismic risk. In November 2005, Ministry of Land, Infrastructure and Transport announced the scandal that several structural designers had fabricated quake-resistance data in designs for condominiums and hotels in Tokyo, Chiba and Kanagawa prefectures, and that some of them might

[7] The actual estimate is -199.75 (in 10,000 yen).

collapse by an earthquake of JMA intensity 5^{-}.[8] Since the majority of rented units are condominiums and the fabrication took place for this type of building, we think that the update seems to be prominent in the housing rent model.[9]

4.3 Changes in Effect of Earthquake Risk by Age of Building

We also include an interaction term between the earthquake occurrence probability and the dummy variables of the age of the building, given the possibility that the impact of earthquake risk on housing prices may depend on earthquake-resistant quality. Table 4 presents the results.

(Table 4 around here)

It is found that the effect of earthquake probability substantially depends on the age of the individual housing unit and that, in general, the estimated risk premium is much larger for older buildings. As for rental housing, the negative effect of earthquake probability is largest for the unit with 20 years or older, and the effect becomes insignificant for relatively new units (ages 15 or less). Similar results, albeit to a lesser extent, can be observed for owner-occupied detached housing. The owner-provided value of detached housing, for which we cannot observe the effect of earthquake probability as a whole (see Table 2), is negatively influenced by the earthquake probability when the age of the unit is 15 – 20 years.

5 Conclusion

The purpose of this paper is to examine the relationships between seismic risk and rental and owner-occupied housing prices in Japan. The earthquake risk premium is estimated using hedonic price models based on the household longitudinal data covering all Japan.

Since earthquake risk is compounded of both the probability of an occurrence and the resulting

[8] Under the 1981 Building Standard Law regulation, buildings must be strong enough to resist a quake of JMA intensity 6^{+}.

[9] There are, however, several other events that can affect the household's perception toward the seismic risk. For example, massive earthquakes such as Mid Niigata Pref. Earthquake in October 2004 (JMA intensity 7), Eastern Fukuoka Pref. Earthquake in March 2005 (JMA intensity 6^{-}), and Miyagi Pref. Earthquake in August 2005 (JMA intensity 6^{-}), had taken place during our sample period.

damage to be expected, we introduce two separate components of earthquake risk, exogenous earthquake occurrence probability and neighborhood dwelling composition as the separate measures of earthquake risk, into our analysis. The results from hedonic regressions provide following empirical findings: (1) the earthquake occurrence probability has significantly negative effect on the monthly housing rent, (2) the effect in the owner-occupied housing market is not so clear as in the rental market; however, the effect seems to depend on the characteristics of the individual housing unit (e.g. age of dwelling), (3) the estimated risk premium is much larger for older buildings, and (4) the share of quake-resistant dwellings in the neighborhood area is significantly and positively related to the housing price of the individual unit.

The result that earthquake occurrence probability is shown to have negative impact on housing rents but not on owner-occupied housing values partially mirrors the fact that the quake-resistant quality is much lower in rental houses. This suggests that the seismic retrofitting for rental housing might be effective policy device for compensating earthquake risks. Also, given that the estimated risk premium is much larger for older buildings, policies aiming at enhancing seismic safety for those buildings might be effective way to mitigate the welfare loss caused by earthquake risk. Furthermore, our result suggests that city-level dwelling composition has large (negative) externality to the neighborhood dwellings, implying that, for example, an urban redevelopment projects for congested wooden dwelling areas will be beneficial not only to the individual unit but also to the neighborhood dwellings.

References

Abrevaya, J. (2002), “Computing Marginal Effects in the Box-Cox Model,” *Econometric Reviews*, **21**(3), pp.383–393.

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**(1), pp.101–113.

Brookshire, D.S., M.A. Thayer, J. Tschirhart, and W.D. Schulze (1985), “A Test of the Expected Utility Model: Evidence from Earthquake Risks,” *Journal of Political Economy*, **93**(2), pp.369–389.

Davidson, R. and J.G. MacKinnon (1993), *Estimation and Inference in Econometrics*, Oxford: Oxford University 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), pp.87–99.

Nakagawa, M., M. Saito, and H. Yamaga (2007), "Earthquake Risks and Land Prices: Evidence from the Tokyo Metropolitan Area," forthcoming in *Japanese Economic Review*.

Naoi, M., K. Sumita, and M. Seko (2007), "Earthquakes and the Quality of Life in Japan," Paper to be presented at the 14th Annual Conference of European Real Estate Society.

Spitzer, J.J. (1984), "Variance Estimates in Models with the Box-Cox Transformation: Implications for Estimation and Hypothesis Testing," *Review of Economics and Statistics*, **66**(4), pp.645–642.

Willis, K.G., and A. Asgary (1997), "The Impact of Earthquake Risk on Housing Markets: Evidence from Tehran Real Estate Agents," *Journal of Housing Research*, **8**(1), pp. 125–136.

Figure 1: Example of the Probabilistic Seismic Hazard Map (PSHM)

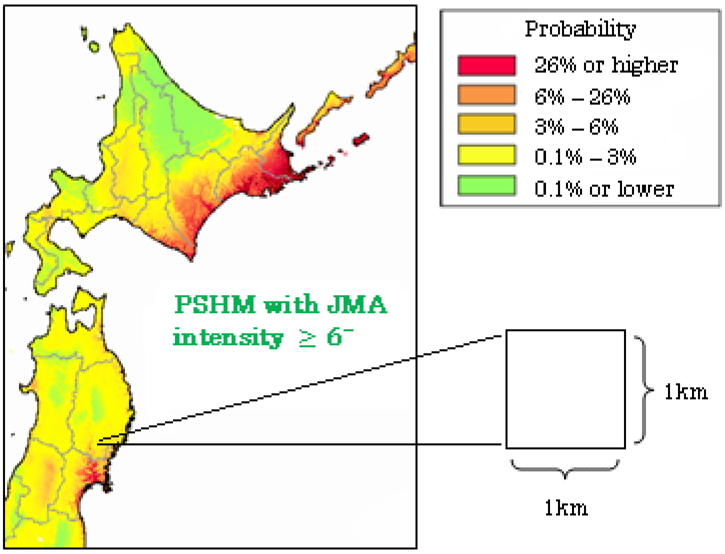

Figure 2: Earthquake Occurrence Probability by Prefecture

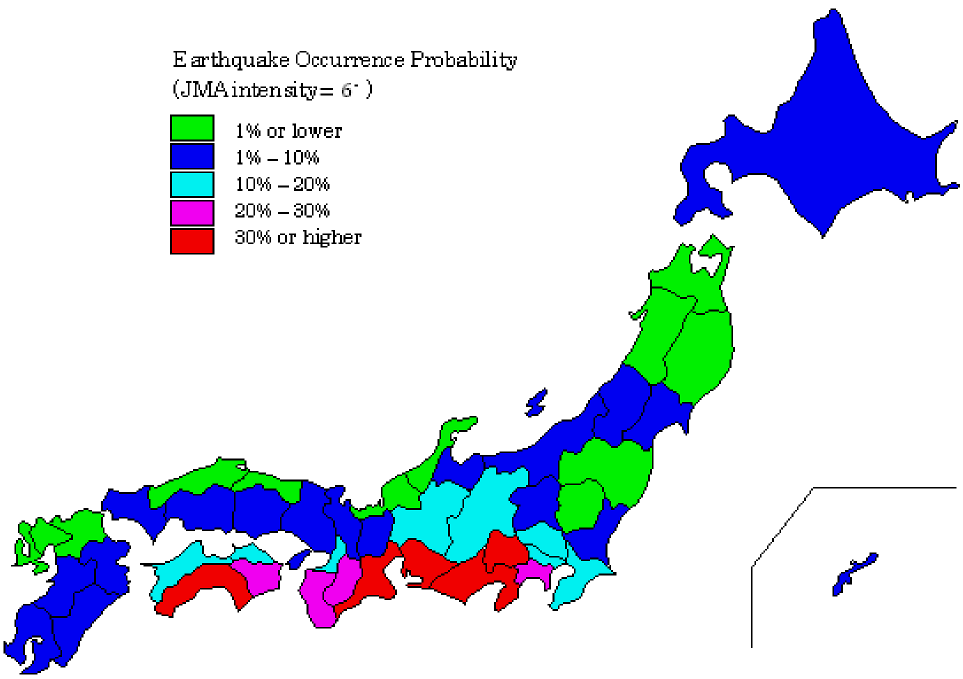

Table 1: Variable Definitions and Summary Statistics

Sample	Renter Households		Homeowners (detached)		Homeowners (detached)		Homeowners (condo)		Homeowners (condo)	
	Mean	(S.D.)	Mean	(S.D.)	Mean	(S.D.)	Mean	(S.D.)	Mean	(S.D.)
Housing Prices										
Housing rent (10,000 yen / month)	6.128	(3.386)	——		——		——		——	
Market price (10,000 yen)	——		3229.0	(4831.1)	——		1777.2	(1675.0)	——	
Assessed value (10,000 yen)	——		——		1372.2	(2258.3)	——		707.7	(1729.4)
Earthquake Risk Indices										
Earthquake occurrence probability (JMA intensity ≥ 6^{-}, within 30 years)	0.150	(0.162)	0.161	(0.195)	0.164	(0.201)	0.143	(0.114)	0.141	(0.119)
Neighborhood dwelling composition										
% wooden	24.261		30.182		30.226		19.449		19.509	
% fire-proofed wooden	28.875	(13.237)	31.526	(14.768)	31.949	(15.009)	31.146	(12.198)	30.956	(12.813)
% steel-framed concrete	7.256	(3.026)	7.015	(3.286)	7.043	(3.324)	7.346	(2.697)	7.270	(2.853)
% concrete	39.351	(15.257)	30.955	(15.396)	30.444	(15.242)	41.897	(12.870)	42.102	(13.164)
% other types	0.257	(0.570)	0.322	(0.682)	0.337	(0.745)	0.161	(0.140)	0.163	(0.144)
Dwelling Characteristics										
Age of the building (years since built)	19.125	(13.012)	20.603	(14.789)	21.297	(15.007)	16.367	(9.180)	17.337	(8.881)
Number of rooms	3.358	(1.171)	6.285	(1.910)	6.388	(1.979)	4.278	(0.823)	4.285	(0.822)
Time-distance from the nearest railway station/bus stop (in min.)	8.674	(7.163)	10.156	(9.617)	10.354	(9.816)	8.083	(6.488)	7.958	(6.313)
Number of stories of the building	3.072	(2.864)	1.915	(0.448)	1.908	(0.458)	7.040	(3.544)	6.924	(3.560)
Floor in which the room is located	1.942	(2.007)	——		——		3.294	(2.309)	3.243	(2.334)
Garden space	——		79.859	(112.690)	84.877	(117.098)	——		——	
N	1577		2665		2168		551		383	

Table 2: Effect of Seismic Risk Measures on Housing Prices

Model	[1]			[2]			[3]			[4]			[5]		
Dependent Variable	Rent (10,000 yen / month)			Market Price (10,000 yen)			Assessed Values (10,000 yen)			Market Price (10,000 yen)			Assessed Values (10,000 yen)		
Sample Used	Renter Households			Homeowners (Detached House)			Homeowners (Detached House)			Homeowners (Condominium)			Homeowners (Condominium)		
	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect
Earthquake Occurrence Probability	-0.7977	8.258 **	-3.2221	-0.7229	1.177	-12.7197	-7.2166	9.311 **	-95.3066	0.1343	0.124	7.6637	-1.6191	0.306	-24.2084
Neighborhood Dwelling Composition															
% wooden		(reference)			(reference)			(reference)			(reference)			(reference)	
% fire-proofed wooden	0.0074	3.750 +	0.0301	-0.0015	0.030	-0.0268	0.0557	3.017 +	0.7357	0.0084	2.356 #	0.4784	0.0389	0.792	0.5815
% steel-framed concrete	0.0214	5.480 *	0.0865	0.1088	14.931 **	1.9138	0.3225	9.372 **	4.2589	0.0074	0.307	0.4234	-0.1104	1.165	-1.6505
% concrete	0.0167	35.748 **	0.0675	0.0479	64.241 **	0.8431	0.0526	5.830 *	0.6941	0.0141	9.257 **	0.8039	0.0377	1.071	0.5640
% other types	0.0868	5.476 *	0.3508	-0.2833	9.295 **	-4.9854	-0.1277	0.160	-1.6859	-0.2475	1.252	-14.1261	-0.8235	0.207	-12.3133
λ	0.3686	(0.0252) **		0.1736	(0.0124) **		0.2727	(0.0107) **		0.0202	(0.0344)		0.1136	(0.0283) **	
N	1577			2665			2168			551			383		
Log Likelihood	-3325.105			-23437.810			-17386.902			-4376.736			-2724.682		

Notes:

**, *, and + indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively. A set of dwelling characteristics and dummy variables for regions and survey years is also controlled but is omitted from the results. For Box-Cox transformation parameter (λ), standard errors are reported instead of likelihood ratio test statistics ($\chi^2(1)$).

Table 3: Effect of Seismic Risk Measures on Housing Prices — Interacted with Survey Year Dummies

Model	[1]			[2]			[3]			[4]			[5]		
Dependent Variable	Rent (10,000 yen / month)			Market Price (10,000 yen)			Assessed Values (10,000 yen)			Market Price (10,000 yen)			Assessed Values (10,000 yen)		
Sample Used	Renter Households			Homeowners (Detached House)			Homeowners (Detached House)			Homeowners (Condominium)			Homeowners (Condominium)		
	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect
Earthquake Occurrence Probability × Survey Year Dummy															
2004	-0.8131	7.353 **	-3.2844	-0.9979	1.715	-17.5580	-9.0334	11.418 **	-119.277	-0.3812	0.694	-23.1953	-1.2089	0.118	-18.1438
2005	-0.6987	4.291 *	-2.8224	-0.3219	0.173	-5.6643	-8.2690	8.771 **	-109.184	0.2154	0.206	13.1075	-3.5846	1.027	-53.8017
2006	-0.8407	6.619 *	-3.3960	-0.8248	1.156	-14.5129	-4.4049	2.600	-58.1622	0.7825	2.388	47.6113	1.0171	0.066	15.2657
Neighborhood Dwelling Composition															
% wooden		(reference)			(reference)			(reference)			(reference)			(reference)	
% fire-proofed wooden	0.0075	3.766 +	0.0302	-0.0015	0.027	-0.0255	0.0552	2.949 +	0.7284	0.0079	2.129	0.4777	0.0399	0.842	0.5991
% steel-framed concrete	0.0214	5.478 *	0.0865	0.1095	15.131 **	1.9272	0.3260	9.523 **	4.3040	0.0084	0.407	0.5125	-0.1084	1.137	-1.6273
% concrete	0.0167	35.648 **	0.0675	0.0480	64.337 **	0.8447	0.0504	5.342 *	0.6660	0.0136	8.836 **	0.8250	0.0375	1.070	0.5634
% other types	0.0868	5.467 *	0.3507	-0.2810	9.136 **	-4.9442	-0.1208	0.143	-1.5951	-0.2708	1.541	-16.4780	-0.8694	0.233	-13.0485
λ	0.3686	(0.0252) **		0.1736	(0.0124) **		0.2731	(0.0107) **		0.0188	(0.0344)		0.1128	(0.0283) **	
N	1577			2665			2168			551			383		
Log Likelihood	-3324.963			-23437.233			-17384.706			-4374.121			-2724.002		

Table 4: Effect of Seismic Risk Measures on Housing Prices — Interacted with Age of the Building

Model		[1]			[2]			[3]			[4]			[5]	
Dependent Variable		Rent (10,000 yen / month)			Market Price (10,000 yen)			Assessed Values (10,000 yen)			Market Price (10,000 yen)			Assessed Values (10,000 yen)	
Sample Used		Renter Households			Homeowners (Detached House)			Homeowners (Detached House)			Homeowners (Condominium)			Homeowners (Condominium)	
	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect	Coef.	$\chi^2(1)$	Marginal Effect
Earthquake Occurrence Probability × Age of the Building (Years since Built)															
Years ≤ 5	0.1795	0.149	0.7268	-1.5833	2.650	-27.8046	-9.3332	6.151 *	-123.147	0.2750	0.253	17.4802	-5.5763	1.514	-81.3381
5 < Years ≤ 10	-0.2558	0.511	-1.0355	-1.3750	2.456	-24.1473	-8.4724	6.871 **	-111.790	-0.3856	0.461	-24.5122	-1.7984	0.131	-26.2325
10 < Years ≤ 15	-0.4229	1.142	-1.7124	-1.1440	1.324	-20.0911	-9.6870	7.875 **	-127.816	-0.0454	0.004	-2.8853	-1.7164	0.093	-25.0354
15 < Years ≤ 20	-0.7299	3.635 +	-2.9550	-2.6033	7.079 **	-45.7181	-9.2926	7.325 **	-122.612	-0.3592	0.287	-22.8318	0.2197	0.002	3.2047
Years > 20	-1.3286	18.753 **	-5.3792	0.3813	0.244	6.6956	-5.5660	4.436 *	-73.4409	1.7672	9.543 **	112.339	0.8556	0.036	12.4804
Neighborhood Dwelling Composition															
% wooden		(reference)			(reference)			(reference)			(reference)			(reference)	
% fire-proofed wooden	0.0090	5.481 *	0.0365	-0.0002	0.000	-0.0033	0.0594	3.368 +	0.7836	0.0111	4.215 *	0.7077	0.0173	0.140	0.2528
% steel-framed concrete	0.0231	6.389 *	0.0933	0.1252	19.088 **	2.1986	0.3464	10.612 **	4.5705	0.0172	1.684	1.0945	-0.1169	1.194	-1.7056
% concrete	0.0162	33.446 **	0.0654	0.0461	57.327 **	0.8097	0.0478	4.726 *	0.6309	0.0138	9.211 **	0.8762	0.0291	0.579	0.4238
% other types	0.0314	0.733	0.1273	-0.2531	7.210 **	-4.4451	-0.0462	0.021	-0.6101	-0.3346	2.341	-21.2686	-1.3665	0.514	-19.9322
λ	0.3676	(0.0251) **		0.1768	(0.0122) **		0.2734	(0.0107) **		0.0179	(0.0341)		0.1193	(0.0283) **	
N		1577			2665			2168			551			383	
Log Likelihood		-3319.820			-23405.292			-17388.130			-4362.689			-2718.834	

Notes:

**, *, and + indicate that the estimated coefficient is significant at the 0.01, 0.05, and 0.10 levels, respectively. A set of dwelling characteristics and dummy variables for regions and survey years is also controlled but is omitted from the results. For Box-Cox transformation parameter (λ), standard errors are reported instead of likelihood ratio test statistics ($\chi^2(1)$).