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Earthquake Risk and Housing Rents: Evidence from the Tokyo Metropolitan Area[1] [2]

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Abstract: We estimate the extent of earthquake risk aversion in housing rents using a 1998 hazard map of the Tokyo Metropolitan Area. These rents reflect earthquake risk generally and the interaction between the earthquake–resistant quality of construction and the risk aversion of households. We find that housing rents are substantially lower in risky areas than in safer areas, even after controlling for other possible effects, and that the rent of an apartment built prior to the Building Standard Law being amended is discounted more substantially in risky areas than those built after this date. In addition, according to a cost–benefit analysis based on these estimation results, investment in earthquake–proof structures is profitable for landlords who own older wood–framed apartment buildings in relatively risky areas given the current level of the government subsidy introduced in 2002.

Keywords: earthquake risk, risk aversion, housing rent, hazard map.

JEL classification: R14, R22, G11.

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1. Introduction

The risk aversion of households and firms towards earthquake risk may be inferred from real estate data in two ways. First, land prices may reflect an earthquake risk premium as compensation, because risk–averse agents tend to avoid land with a high degree of earthquake–related danger. Second, housing rents may also reflect information concerning the degree of the earthquake–resistant quality of construction, in that risk–averse agents may prefer more solidly built structures as well as geographically safer places. This paper empirically examines the latter issue, while a companion paper (Nakagawa, Saito, and Yamaga, 2004) addresses the former.

There have been few empirical studies on the effect of earthquake risk on land prices in the field of urban and regional economics. Among those undertaken, Beron et al. (1997) compare the residential prices in the San Francisco Bay area before and after the 1989 Loma Prieta Earthquake. Their study suggests that residents revised the assessment of earthquake risk after the earthquake occurred. Brookshire et al. (1985) found significant impacts on land pricing after the disclosure of a hazard map constructed by the State Government of California. Nakagawa et al. (2004) empirically addressed the effect of earthquake risk on land pricing using the index of earthquake risk compiled for the entire metropolitan area by the Tokyo Metropolitan Government (Bureau of Urban Development, 1998). They demonstrated that land prices were low in areas with substantial exposure to earthquake risk.

On the other hand, and to the best of our knowledge, there have been no empirical studies concerning the effect of earthquake risk on housing rents. This paper empirically examines the extent to which earthquake risk is reflected in housing rents in the Tokyo Metropolitan Area, adopting the same earthquake risk index as used by Nakagawa et al. (2004). In particular, we pay attention to how the effect of earthquake risk on housing rents depends on the structure of the rented house. We find that earthquake risk is reflected in housing rents to a large extent even after controlling for other possible effects; that is, housing rents are substantially lower in the areas with exposure to earthquake risk. We also find that the effect of earthquake risk on housing rents largely depends on the robustness of the rented house. For the purposes of estimating the latter, we exploit the fact that the Building Standard Law was amended in 1981 to enhance the earthquake–resistant quality of buildings, and that a building constructed after 1981 needed to conform to the new standard of earthquake–resistant quality.[3] According to our estimations, the rent of houses built prior to 1981 is discounted more substantially in risky areas than that of houses built after 1981.

These findings have important policy implications for the construction of earthquake–proof measures in Japan. For example, the Architectural Institute of Japan (1997) documented that 95% of the buildings that collapsed in the Great Hanshin–Awaji Earthquake (January, 1995) were constructed under the old building code, while wooden houses suffered more than other types of structure. According to the Housing Bureau (2001), few of such wooden apartments are subject to on–site assessment of earthquake–resistant quality, and one quarter of wood–framed houses would indeed be rated as having extremely high exposure to the risk of housing collapse. From the viewpoint of disaster countermeasures, it is then important to renovate buildings constructed under the old code in risky areas.

Our investigation also suggests that disaster prevention investment against earthquake risk may be beneficial for owners of rented houses. We take as a case study the subsidy for the antiseismic system improvement that started in 2002, and examine whether apartment owners would benefit from an increase in apartment rents due to

[3] While the Building Standard Law was amended several times, the 1981 amendment was the most significant one,

investment in earthquake–resistance measures. Under this system of subsidies, the Japanese government provides subsidies to cover 7.7% of renovation costs. According to our cost–benefit analysis, the investment in earthquake–proof structures would indeed be profitable for landlords who own older wood–framed apartments in relatively risky areas. This case study may then serve as an important example of how policy measures use market evaluation (pricing of housing rents in this particular case) as an instrument to promote disaster prevention in a decentralized manner.

This paper is organized as follows. Section 2 presents the empirical specification, and reports the estimated results. Section 3 examines whether investment in antiseismic systems is beneficial for landlords on the basis of cost–benefit analysis. Section 4 concludes by discussing the policy implications for disaster countermeasures.

2. Data and estimation results

2.1 Data

Following a standard hedonic pricing approach, this section investigates the impact of earthquake risk on housing rents. As described below, we collect a set of explanatory variables, including an index of earthquake risk, and variables concerning the characteristics and location of rental houses.

2.1.1 Earthquake risk indices

While the Tokyo Metropolitan Government has compiled an earthquake hazard map about every five years since 1975, it released the most elaborate earthquake hazard map on a seven–digit postcode basis for the entire Tokyo metropolitan area (except for western rural areas) in March 1998 (Bureau of Urban Development, 1998). These data have been made available through the Tokyo Metropolitan Government website since

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and it included a drastic revision concerning the earthquake–resistant quality of buildings.

1998.[4] Importantly, the construction of the earthquake risk index in the 1998 version is not an assessment of specific damage by a predicted earthquake. Rather, it is an assessment of the comparative vulnerability of finely divided regions (on a seven–digit postcode basis) in terms of: (i) potential damage to buildings due to initial earthquake shocks; (ii) potential damage to buildings due to consequent fires; (iii) potential human injuries due to initial earthquake shocks; and (iv) potential human injuries due to consequent fires. Each index classifies the degree of riskiness according to five ranks, from Rank 1 (safest) to Rank 5 (riskiest).

Our study uses the 1998 version of the risk index of potential damage to buildings due to initial earthquake shocks (the building collapse risk). A major reason for adopting the building collapse risk among the four indices is that this index mainly considers: (a) the quality of the ground structure; and (b) earthquake–resistant properties of constructions in the ground area. More particularly, the risk index is lower if the ground of an affected area is solid, or if robust constructions are built on an affected area. The other three indices take into consideration not only ground and building condition but also area congestion. Such area congestion, however, often according with regional concentration, may have a positive externality as a result of agglomeration effects on housing rents, while it may indeed trigger negative externality on them by congestion effects. We thus use the first index in order to avoid offsetting or amplifying effects on housing rents.[5] We add this ascending risk scale of 1 to 5 to the list of explanatory variables in the rent pricing function.

[4] The latest version is available from the web site; http://www.toshiseibi.metro.tokyo.jp/bosai/chousa_5/home.htm (in Japanese).
[5] Even if the first principal factor among the four indices, estimated by factor analysis, is adopted as an alternative risk index, then our estimation and simulation results do not change substantially.

Among the sample of housing rents described in the next subsection (82,410 surveyed points), 21,748 rented houses are located in Rank 1; 35,669 in Rank 2; 19,007 in Rank 3; 5,014 in Rank 4; and 972 in Rank 5.

2.1.2 Housing rents and characteristics

This study adopts housing rents and characteristics available from Recruit (2002), which is the largest web–accessible rental housing information database in Japan. This dataset includes housing rents (on offer rent basis) as well as detailed information about rental housing characteristics. We use the dataset of monthly housing rents in the Tokyo Metropolitan Area collected as at the end of January 2002 by Recruit (2002).

Following the existing literature on the hedonic pricing approach applied to Japanese cities (for example, Gao and Asami, 2001; Kanemoto and Nakamura, 1986; and Kanemoto et al. 1996), we collect the following variables from Recruit (2002) as explanatory variables, thereby controlling for possible effects on housing rents. These include: the walking time (bus time) from home to the nearest station, floor space, building age, the number of floors, and a first floor dummy in addition to a set of dummy variables of types of building and construction materials used as described later.

In choosing explanatory variables, we also consider environmental effects on housing rents other than earthquake risk, in particular regional differences in economic status. First, the average household income is available city by city (or ward by ward) from the Japan Marketing Education Center (2000), which reports the regional average income for the whole region of Japan. Second, we obtain data concerning land–use classification from the Bureau of Urban Development (2002). This survey reports, on a seven–digit postcode basis, the ground area proportion (relative to the seven–digit postcode area) of types of facilities or constructions (residential, educational/cultural, medical, utilities/disposal, commercial, medical, accommodation, sporting facilities, and factory uses). Third, we construct a dummy variable associated with the 23 special wards, where some public services are designated by both municipality and the Tokyo Metropolitan Government. Fourth, we add nearest commuter lines as dummy variables. Finally, we calculate the travel time from the nearest station to the central business district (Tokyo Station), according to the 2000 train timetable.[6]

The 82,410 surveyed points are distributed over more than 80% of the Tokyo Metropolitan Area on a seven–digit postcode basis. Thus the sample of our dataset is not severely biased toward particular regions or subject to geographical clustering. Although our estimation procedure does not consider spatial correlation explicitly, given less geographical clustering, standard errors of the ordinary least squares (OLS) estimates may not be seriously biased.[7] In this dataset, there are two types of buildings, fireproof and non–fireproof, and three types of construction materials: steel–framed, steel–reinforced concrete, and wood–framed construction.

As discussed earlier, a drastic amendment of the Building Standard Law was made in 1981. Consequently, any apartment building constructed after 1981 must conform to a new standard of earthquake–resistant quality. To control for the effect of this amendment on housing rents, we introduce a dummy variable that takes a value of one for apartment buildings constructed after 1981, otherwise zero. The construction of the above dummy variable can be justified by not only the historical circumstance, but also the following statistical inference. As of 2002 when the above housing rents were collected, a building less than 21 years old was subject to the new standard (introduced in June, 1981), while a building older than 21 years was subject to the old standard. We

[6] For this purpose, we use a software package provided by VAL Institute (http://val.co.jp).
[7] The consideration of spatial correlation is still potentially important, and we would like to leave it to a future research.

test a hypothesis that there is no structural break at the age of 21 by considering at most one break point in the year 1981. Applying the Chow test to the housing rent models described later (Models I and II), we reject this null-hypothesis at the 1% level of significance.

We also include an interaction term between the earthquake risk index and the new building standard dummy variable, given the possibility that the impact of earthquake risk on housing rents may be different under the old and new standards of earthquake–resistant quality. We also consider the possibility that the impact of earthquake risk on housing rents may differ according to buildings' construction materials by adding interaction terms between the earthquake risk index and the dummies for construction material.

Given the above construction of the explanatory variables, the coefficient on the risk index multiplied by a construction–type dummy represents the risk impact under the old standard, while the coefficient on the risk index multiplied by a construction–type dummy and a new standard dummy corresponds to the difference in the risk impact between under the new and old standards. Table 1 presents descriptive statistics for the major explanatory variables used in this study.

2.2 Estimation results

Table 2 presents the results of an OLS estimation based on two types of specification, entitled Model I and Model II. Except for the earthquake index, land–use classification variables and dummy variables, all independent variables (including housing rents as a dependent variable) are expressed in logarithmic form. All reported standard errors are robust with respect to heteroscedasticity.

According to the results of Model I, all estimated coefficients on the travel time to Tokyo Station, the road distance to the nearest station and floor space are generally reasonable in sign at the 1% level of significance. Coefficients on the 23 special–ward dummy variable and the regional average of household income are positive. In addition, estimated coefficients on each of land–use classification variables are reasonable in sign at the 1% level of significance. An increase in the percentage of utilities/disposal facilities, industrial districts, and sporting facilities has negative impacts on housing rent, while the other types of land use have positive effects.

One interesting observation is that the number of floors is significantly positive (the higher the floor, the higher the rent), while the estimated coefficient on the first floor dummy variable is also significantly positive. In terms of earthquake risk, [8] the former result may indicate that lower floors are more likely to be crushed, while the latter may imply that it is easier to evacuate from the first floor.[9]

According to the coefficients on the variables associated with housing types, the rent of buildings with fireproof construction is significantly higher than that of those with non–fireproof construction. In addition, the rent of houses constructed under the new standard is significantly higher than those constructed under the old standard.

With respect to the effect of the earthquake risk index on housing rents, all coefficients on the indices associated with the buildings under the old standard are significantly negative, despite differences across construction types, namely steel–framed, steel–reinforced concrete, and wood–framed buildings. These results suggest that the rent of a house built on lower risk ground is substantially higher than that of a

[8] Except for the aspect of earthquake risk, the first floor has merits and demerits. While the first floor is less secure against invasion, it often features a private garden and direct access to the outside. In addition, there is strong preference for the first floor among those who have a preference for detached houses in Japan. A positive coefficient on the first floor dummy may pick up these advantages as well.

[9] According to additional estimation results, preference for the first and higher floors is weaker in the rented apartments built under the new standard. Those results may imply that the buildings under the new standard are less

house built on higher risk ground. The impact of housing rents with respect to the risk index is highest for wood–framed housing (–0.0367), and lowest for steel–reinforced concrete housing (–0.0175); that is, the rent of the least robust structure is most sensitive to earthquake risk.

In comparison between houses built under the new standard and under the old standard, the risk sensitivity under the new building code is reduced across construction types. Particularly in the case of wood–framed houses, the risk sensitivity under the new standard is substantially lower than that under the old standard, as the estimated coefficient on the interaction term among the risk index, the wood–framed dummy, and the new standard dummy demonstrates. An F–test of the zero–sum of the estimated coefficients on wood–framed under the old standard (–0.0367) and under the new standard (0.0458) is rejected at the 1% level of significance. That is, the riskier the index, the higher the housing rent under the new standard. This finding about the relationship between the risk index and the housing rent is further analyzed in the next specification (Model II).

The estimation results based on Model I indicate that the introduction of the new standard has greatly enhanced the quality of wood–framed construction in earthquake–hazardous areas. To investigate this aspect in more detail, we treat the quality of construction of wood–framed housing more explicitly. For this purpose, Model II introduces an interaction term between the logarithm of building age and the risk index, in addition to the set of explanatory variables used in Model I.

As shown in the second column of Table 2, all estimated coefficients, other than those associated with the risk index, do not substantially differ between Model I and Model II. Figure 1 highlights the effect of building ages on the risk impact of wood–

subject to earthquake–related risks, such as crushing and failing to escape.

framed housing rents using the results of Model II. Note that a building less than 21 years old is subject to the new standard (introduced in June, 1981), while a building older than 21 years is subject to the old standard. Note that the dataset used records of housing rents as at January 2002.

As shown in Figure 1, there are four interesting features with respect to the risk impact of wood–framed housing rents. First, there is a downward jump at the age of 21. As pointed out earlier, this discontinuity in the impact indicates that the new building code has substantially enhanced the earthquake–proof quality of wood–framed buildings. Second, despite whether the building was constructed under the old or new standard, the value of the risk impact coefficient decreases with building age. Third, the risk impact curve of buildings under the old standard is steeper than that of buildings under the new standard, implying that the risk impact is more sensitive to building age under the old standard. Fourth, the risk impact of buildings under the new standard is positive. The final point may indicate that the quality of wood–framed buildings under the new standard is fairly high in the more hazardous areas.

Table 3 presents the predicted housing rent according to building age for a room on the first floor of a wood–framed and non–fireproof apartment building located in the riskiest area (Rank 5) in Sumida Ward for both models. In addition, we assume the following conditions: the walking time to the nearest station is nine minutes, the travel time to Tokyo Station is 30 minutes, and the floor space is 30 square meters. In Model I, the predicted rent of the building under the new standard is about 35% higher than that under the old standard. On the other hand, in the Model II specification, the percentage difference between the former and the latter ranges from 29.1% to 53.3%. These calibrated rents are used for the cost–benefit analysis of earthquake–proof investment in Section 3.

Finally, we explore whether the risk index may act as a proxy for environmental variables such as amenity and convenience. We argue against this on the following basis. First, to a great extent, our well prepared list of explanatory variables is able to control for environmental effects on housing rents. The walking/bus travel time to the nearest station and the travel time to Tokyo Station act as proxies for commuting convenience. The environmental variables, including the regional average of household income, the land–use classification, the 23 special–ward dummy, and nearest commuter lines dummies, can control for segmentation effects due to the income class and the neighborhood environment.

Second, not the risk index itself, but its interaction with the type of building construction may reflect environment factors indirectly, if constructions and regional environment are correlated with each other. Our dataset, however, allows us to control for this possible effect, because there are different types of building construction within the same seven–digit postcode area on which basis the regional risk index is constructed. More specifically, among the 4105 seven–digit postcode areas in our sample, 1309 areas have two types, while 1717 areas have three building types or more. Nevertheless, we find that the estimated coefficients on the risk index depend on the type of building construction. It is thus difficult to believe that the effect of environmental factors other than earthquake risk on housing rents would interact with the construction type.

Finally, Nakagawa et al. (2004), who analyze the effect of earthquake risk on land pricing, demonstrate that the same risk index yields quite reasonable effects on land prices as well. Together, these qualify the validity of the current index as being representative of earthquake risk alone.

3. Cost–benefit analysis of an antiseismic system improvement of housing

3.1 Averaged evaluation of an antiseismic system improvement

The preceding estimation results indicate that if an owner of the apartment built prior to 1981 conforms his apartment to the new standard by the antiseismic system improvement, then he may receive increases in rents. Using the estimation results from Section 2, this section estimates the net profits of a landlord when an antiseismic system improvement of housing is implemented.

More specifically, we compare the net present value of future cash flows to a landlord's profit (NPV) of undertaking seismic improvements on the building today with the NPV of never undertaking seismic improvements on the building. The NPV is therefore calculated as the difference between an increase in housing rents due to an antiseismic system improvement and its implementation cost:

$$NPV = \sum_{t=1}^{m} \frac{r^N}{(1+i^N)^t} - \sum_{t=1}^{m} \frac{r^O}{(1+i^O)^t} - C \, , \tag{1}$$

where r^N is the housing rent with the antiseismic system improvement , r^O is the housing rent without it, and C is the cost of antiseismic system improvements. As described below, applicable discount rates (i^N and i^O) depend on whether the seismic improvement is implemented or not. We then calculate whether the net present value is positive.

According to the System of National Accounts compiled by the Agency of Economic Planning, the life of residential buildings is approximately 42 years. As a 22–year–old apartment building in 2002 is adopted as the reference case, the life remaining is twenty years (m). It also means that this old apartment block was built under the old building code. We then assume that an increase in housing rents due to antiseismic improvements corresponds to the estimated difference in rents under the old and new building codes.

We also consider the possibility of the loss of rent revenues as a result of complete housing demolition by an earthquake in constructing discount rates applicable to rented apartments without any antiseismic improvement (i^O). We compute i^O by adding the probability of complete demolition to real interest rates under the assumption that a demolition event occurs according to the Poisson process. We adopt as the real interest rate, the average mortgage rate adjusted by the consumer price index between 1987 and 1999 in Japan, or 3.52% per annum. Then, the demolition probability is set at 1% for the following reason. For the period between 1600 and 2000, an earthquake with a magnitude of higher than 6.0 occurred every twenty years on average in the Kanto Region including the Tokyo Metropolitan Area. That is, the annual occurrence of catastrophic earthquakes is equal to around 5%. According to the Tokyo Metropolitan Disaster Prevention Council (1997), about 20% of the residential buildings located in the Tokyo Metropolitan Area will be destroyed, if a direct underneath–type earthquake occurs there. We thus estimate the probability of housing demolition as 1% (5% times 20%), and use 4.52% (3.52% plus 1%) as a relevant discount rate (i^O) for the cost–benefit analysis.[10]

We consider two cases for discount rates applicable to apartments with antiseismic improvements (i^N). In the first case, improved apartments are not exposed to any demolition risk by an earthquake; that is, i^N is equal to 3.52%. In the second case, renovated apartments are partially subject to demolition risks. We here assume that i^N is larger than the real interest rate by 0.5% (i^N = 4.02%). The second case yields more conservative estimates or lower net benefits than the first.

[10] In principle, if interest-rate risks are correlated with earthquake risks, then risk premiums should be added to discount rates. However, because we know little about the covariance between the two risks, our construction of discount rates does not consider this respect.

We then conduct a cost–benefit analysis of antiseismic improvements for the above type of apartment building. As shown below, the overall net benefit to a landlord is still negative despite the government subsidy introduced in 2002. According to the estimation results of Model I concerning the rented houses built from 1982 and those built before 1981, landlords of rented houses would receive, on the weighted average of all types of constructions (i.e., steel–framed, steel–reinforced concrete, and wood–framed), an 11.1% increase in apartment rents due to antiseismic system improvements. Because the average monthly housing rent of a 22–year–old house located in Tokyo is 68,374 yen per unit at 2002 consumer prices (Statistics Bureau, 1998), the present value of increases in future rents would amount to about 2,173,000 yen under the first assumption (i^N = 3.52%). According to the Housing Bureau (2001), the average antiseismic system improvement cost (C) is around three million yen per unit at 2002 consumer prices. The government subsidy covers 7.7% of renovation costs. Given these assumptions, the net present value of antiseismic improvements attributed to the landlord would be negative or –596,000 yen,[11] despite the government subsidy.

3.2 Cost–benefit analysis of wood–framed apartment buildings

As demonstrated in the earlier section, however, the risk sensitivity of housing rents depends largely on the fragility of construction, and there is a substantial difference in rents of wood–framed apartment buildings under the old and new building codes. Thus, the net benefit to a landlord might be positive for old wooden apartment buildings located in areas with high exposure to earthquake risk, and therefore our analysis below will focus on the case with wooden constructions.[12]

[11] The corresponding calculation is: $2{,}173{,}000 - 3{,}000{,}000 \times (1 - 0.077) = -596{,}000$.

[12] According to our calculation (not reported in this paper), the impact of earthquake–resistance measures on housing rents are rather small for types of structures other than wooden constructions, and the net–benefit of investment in

We explore such a possibility by a cost–benefit analysis of antiseismic system improvements designed for a 22–year–old wood–framed apartment building under exactly the same assumptions as those used in Table 3. That is, the reference apartment unit is 22 years old on the first floor of a wood–framed and non–fireproof building located in Sumida Ward.[13]

Under the two different assumptions about i^N (3.52% and 4.02%), Table 4 reports the calibrated net profit to a landlord for the case without any subsidy, columns (1) and (3), and the case with the government subsidy amounting to 7.7% of antiseismic system improvement costs under existing laws, columns (2) and (4). The predicted housing rents of wood–framed buildings before and after earthquake-proof renovation are calculated in the same way as in Table 3.

Under the first assumption (i^N = 3.52%), as shown in columns (1) and (2), the net profit to landlord is negative with and without the government subsidy for the safest area (Rank 1). However, net profits are positive for the relatively risky areas (Rank 2, 3, 4 and 5) with and without the government subsidy. Under the second assumption (i^N = 4.02%), as shown in columns (3) and (4) of Model I, the net profit for the Rank 1, 2 and 3 areas is negative without the government subsidy. Even with the government subsidy, the net profit for the Rank 1 and 2 areas is still negative. The cost–benefit analysis based on Model II is a little more pessimistic. Nevertheless, the government subsidy raises the net profit toward definitely positive signs in the Rank 4 and 5 areas. In sum, the above cost–benefit analysis proves that the antiseismic system improvement of wood–framed apartment buildings in relatively risky areas would be beneficial to landlords in terms of net present value.

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earthquake–proof structures turns out to be negative in all cases.

[13] We make the following assumptions: the walking time to the nearest station is nine minutes, the travel time to

Finally, we point out that the result of the cost–benefit analysis developed in Section 3 itself confirms the following assumptions implicit in our estimation and cost–benefit analysis. That is, we have implicitly assumed that (i) the old standard was strictly binding for all the constructions built under the old code, or the rented apartments built prior to 1981 were never beyond the earthquake–resistant quality required by the old standard, and that (ii) the buildings constructed before 1981 never received any earthquake–resistance measures after 1982. As discussed in Section 3.1, even with the government subsidy, the net present value of antiseismic system improvements attributed to landlords would be negative on the average, and therefore, the current owner of an apartment built prior to 1981 would not have strong incentive to improve its earthquake–resistant quality. Our implicit assumptions are thus verified.[14]

4. Conclusion

As shown in Section 3, the landlord who owns an old wood–framed apartment building in a risky area would benefit from investment in earthquake–resistance measures, mainly because of the substantial improvement in housing rents. Nevertheless, few landlords have voluntarily exploited this opportunity. Indeed, instead of voluntary actions by landlords, local governments often designate some apartment owners, and force them to renovate their rented apartments.[15]

Tokyo Station is 30 minutes, and the floor space is 30 square meters.

[14] The assumption (i) may be confirmed by circumstantial evidence. It is hard to imagine that landlords would have incentives to build structures beyond the required earthquake–proof quality in spite of high costs before 1981, given insufficient recognition concerning antiseismic measures among landlords and tenants. According to the Housing Bureau (2001), 86%of 6039 wood–framed houses that were built prior to 1980 are not rated as earthquake–resistant quality constructions by on–site assessment. With respect to the assumption (ii), on the other hand, in our dataset we cannot identify whether the rented constructions built before 1981 were retrofitted for the earthquake–resistance enhancement. Consequently, we cannot directly verify our implicit assumptions using our dataset.

[15] In Japan, the public earthquake insurance system for residential constructions including rented apartments is operated jointly by the central government and private insurance companies. The premiums, however, are related only loosely to the robustness of constructions. Accordingly, there is little room for this insurance system to affect decisions of landlords and tenants for antiseismic improvements.

One major reason for this apparent unwillingness of landlords to renovate their apartments is that tenants are heavily protected under the Tenant Protection Law in Japan. Under this law, rents are strictly controlled within tenancies, while in principle rents are free to vary between tenancies. This law however has two particular characteristics as follows. First, the owner must have very legitimate reasons in order to terminate the existing contract.[16] In other words, there is no explicit termination date in the contract. Second, the owner cannot evict the incumbent tenant who refuses a rent increase, while the rent is negotiated between landlord and tenants at the beginning of the contract.[17] That is, once a tenant opposes renovation for earthquake–resistance purposes, landlords are subject to court decisions to cancel existing lease contracts.[18] Such legal aspects might make the antiseismic system improvement more costly than that estimated in Section 3.[19]

As shown by research on the Great Hanshin–Awaji Earthquake, including that conducted by the Architectural Institute of Japan (1997), houses with inferior earthquake–resistant quality triggered large negative externalities in the neighborhood. For example, broken fragile houses blocked transportation networks, thereby preventing effective fire fighting and, by severing lifelines, they made recovery more difficult. In this regard, improvements in the earthquake–resistant quality of apartment buildings would not only benefit apartment owners directly, but would also indirectly benefit

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[16] In order to terminate a contract despite a tenant's desire for renewal, a landlord needs to justify his just course at court. Then, a court carefully compares landlord's claims with tenant's economic necessities, and often judge in favor of a tenant. Similarly, a landlord has to justify an increase in rents at court after an incumbent tenant's refusal.

[17] As Arnott (2003) discusses, this form of tenancy rent control often results in negative incentives for landlords to rehabilitate, demolish, or reconstruct rented houses.

[18] Although a regulatory framework (called the Act Concerning Promotion of the Improvement of Disaster Prevention Block in the Densely Built–up Area) granted an exemption to the Tenant Protection Law for fire prevention purposes in 1997, that exemption clause has not been applied to any case of antiseismic improvements.

[19] The Fixed–Term House Lease System, introduced in 2000, allows landlords to terminate a rental contract at a predetermined date, and to refuse its renewal. While this system may enhance the bargaining power of landlords relative to tenants in the future, there are still very few houses based currently on the above system. Our sample includes only 305 rented houses based on this new system (0.37% of the sample). The estimated results do not depend on whether these observations are included or excluded. Therefore, we report the estimated results based on

other neighborhood residents. In consideration of externalities, it is then crucial to construct an environment in which landlords easily and voluntarily renovate their own apartments for earthquake–resistance purposes. With additional subsidies to landlords, and Tenant Protection Law deregulation, the positive externalities of investment in disaster prevention may then be fully exploited.

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Table 1: Descriptive Statistics of Dependent and Independent Variables

Variables	Mean / Frequency	Standard Deviation
Housing rents (yen)	122229.80	83946.94
Earthquake risk (%)		
Rank 1 area (safest)	26.39	
Rank 2 area	43.28	
Rank 3 area	23.06	
Rank 4 area	6.08	
Rank 5 area (riskiest)	1.18	
Fireproof building dummy	0.78	0.42
New standard building dummy	0.88	0.33
Bus time (minutes) (1)	0.31	1.99
Walking time (minutes)	7.41	4.32
Travel time to CBD (Tokyo Station) (minutes)	30.51	11.96
Floor space (square meters)	38.47	22.04
Building age (years)	11.46	8.24
Floor number	3.20	2.84
First floor dummy	0.24	0.43
Building structure dummy		
Steel–framed	0.19	0.39
Steel–reinforced concrete	0.66	0.48
Wood–framed	0.15	0.36
Average household income (thousand yen)	4827.21	841.75
Ground area proportion by land–use (%)		
Residential facilities	61.50	19.91
Educational/cultural facilities	9.42	10.51
Medical facilities	1.35	2.86
Utilities/disposal facilities	0.60	3.10
Commercial facilities	2.08	2.98
Accommodation facilities	0.84	2.89
Sporting facilities	0.63	2.54
Factories	2.02	4.71
23 special–ward dummy	0.84	0.36

(1) The share of bus users is 2.69%. The average bus time conditional on the bus usage as commuting, is 11.43 minutes.

Table 2: Estimation Results of Rent Pricing Functions

	Model I		Model II	
Constant (old standard and non fireproof)	5.3234***	(0.0473)	5.3208***	(0.0473)
Fireproof dummy	0.0698***	(0.0023)	0.0700***	(0.0023)
New standard dummy	0.0710***	(0.0045)	0.0721***	(0.0045)
Risk index × steel–framed dummy	-0.0303***	(0.0027)	-0.0301***	(0.0027)
Risk index ×steel–reinforced concrete dummy	-0.0175***	(0.0020)	-0.0172***	(0.0020)
Risk index × wood–framed dummy	-0.0367***	(0.0023)	0.1040***	(0.0249)
Risk index × wood–framed dummy × building age			-0.0429***	(0.0076)
New standard × risk index × steel–framed dummy	0.0100***	(0.0027)	0.0097***	(0.0027)
New standard × risk index × steel–reinforced concrete dummy	0.0111***	(0.0020)	0.0108***	(0.0020)
New standard × risk index × wood–framed dummy	0.0458***	(0.0023)	-0.0922***	(0.0250)
New standard × risk index × wood–framed dummy × building age			0.0417***	(0.0076)
Bus time	-0.0966***	(0.0016)	-0.0966***	(0.0016)
Walking time	-0.0389***	(0.0009)	-0.0389***	(0.0009)
Travel time to CBD (Tokyo Station)	-0.1348***	(0.0027)	-0.1347***	(0.0027)
Floor space	0.7368***	(0.0012)	0.7367***	(0.0012)
Building age	-0.0362***	(0.0006)	-0.0359***	(0.0006)
Floor number	0.0468***	(0.0014)	0.0469***	(0.0014)
First floor dummy	0.0160***	(0.0020)	0.0160***	(0.0020)
Average household income	0.4596***	(0.0050)	0.4597***	(0.0050)
Land–use: Residential facilities	0.0009***	(0.0001)	0.0009***	(0.0001)
Educational/cultural facilities	0.0007***	(0.0001)	0.0007***	(0.0001)
Medical facilities	0.0025***	(0.0002)	0.0025***	(0.0002)
Utilities/disposal facilities	-0.0010***	(0.0002)	-0.0010***	(0.0002)
Commercial facilities	0.0011***	(0.0002)	0.0011***	(0.0002)
Accommodation facilities	0.0041***	(0.0002)	0.0041***	(0.0002)
Sporting facilities	-0.0027***	(0.0003)	-0.0027***	(0.0003)
Factories	-0.0020***	(0.0001)	-0.0020***	(0.0001)
23 special–ward dummy	0.1788***	(0.0025)	0.1789***	(0.0025)
Adjusted R square	0.90		0.90	
F–value (P–value)	7826.92 (0.00)		7661.94 (0.00)	
Number of observations	82410		82410	

(1) The figures in parenthesis are heteroscedasticity–robust standard errors.
(2) *** indicates the 1% level of significance.
(3) The estimated coefficients of the dummy variables of railroad lines are not reported.
(4) The constant term represents the following base conditions: the building is old standard and non fireproof and is located near the station of Oedo Line in Sumida Ward.
(5) The F–value evaluates the null hypothesis that coefficients on all independent variables in the model equal zero.

Table 3: Predicted Housing Rents of Wood–Framed and Non–Fireproof Apartment Buildings Located in the Riskiest Area (unit: thousand yen)

	Model I			Model II		
Building age (year)	New standard	Old standard	Difference	New standard	Old standard	Difference
1	93.97			95.24		
5	88.66			89.01		
10	86.46			86.46		
21	84.17			83.80		
22	84.03	62.26	21.77 (34.96%)	83.64	64.76	18.88 (29.15%)
30	83.09	61.57	21.52 (34.96%)	82.55	59.92	22.64 (37.78%)
40	82.23	60.93	21.30 (34.96%)	81.56	55.75	25.81 (46.30%)
50	81.57	60.44	21.13 (34.96%)	80.80	52.72	28.08 (53.27%)

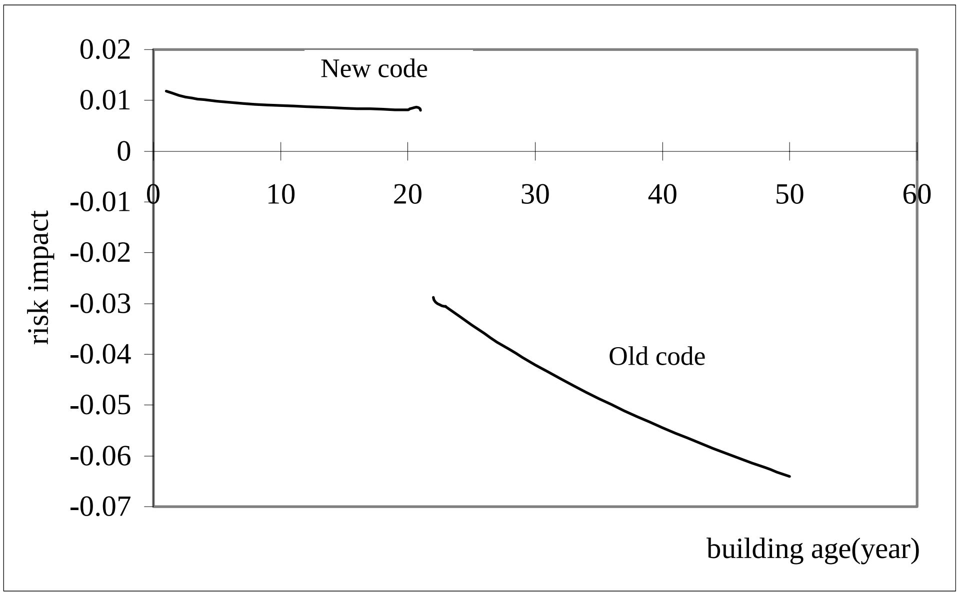
The housing rent is calculated for a room on the first floor of a wood–framed and non–fireproof apartment located in the Rank 5 area in Sumida Ward. The following characteristics are also assumed: the walking time to the nearest station is nine minutes, the travel time to Tokyo Station is 30 minutes, and the floor space is 30 m^2.

Table 4: Cost–Benefit Analysis of Antiseismic System Improvements of Wood–Framed Apartment Buildings (unit: thousand yen)

		Net profits to landlord			
		i^N=0.0352%, i^O=0.0452%		i^N=0.0402%, i^O=0.0452%	
		0% subsidy (1)	7.7% subsidy (2)	0% subsidy (3)	7.7% subsidy (4)
Model I	Rank 1	-440.10	-209.1	-1043.53	-812.53
	Rank 2	89.32	320.32	-519.54	-288.54
	Rank 3	606.42	837.42	-7.96	223.04
	Rank 4	1111.19	1342.19	491.24	722.24
	Rank 5	1603.65	1834.65	978.03	1209.03
Model II	Rank 1	-531.2	-300.2	-1134.26	-903.26
	Rank 2	-97.84	133.16	-705.81	-474.81
	Rank 3	324.46	555.46	-288.35	-57.35
	Rank 4	739.12	970.12	121.4	352.4
	Rank 5	1147.69	1378.69	524.98	755.98

The housing rent is calculated for a room on the first floor of a wood–framed and non–fireproof apartment located in the Rank 5 area in Sumida Ward. The following characteristics are also assumed: the walking time to the nearest station is nine minutes, the travel time to Tokyo Station is 30 minutes, and the floor space is 30 m^2.

Figure 1: Risk Impact of Wood–Framed Housing Rents with respect to Building Age



The risk impact (a marginal effect of the risk index on housing rents) is based on the estimated coefficients on the risk index (β for the old code and β_{new} for the new code), and those on the interaction term between the logarithmic building age and the risk index (γ for the old code and γ_{new} for the new code) for the wood–framed building. More specifically, the risk impact up to the age of 20 is computed from $\beta + \beta_{new} + (\gamma + \gamma_{new})\ln(age)$, while the risk impact of the age of 21 or older is calculated from $\beta + \gamma \ln(age)$.