

Spatial Hedonic Analysis of Housing Prices in Earthquake-Prone Areas: Evidence from Yogyakarta, Indonesia

¹Endah Saptutyningsih, ²Salwa Fauziyyah Hermawan, ³Romi Bhakti Hartarto* and ⁴Nursetiawan

^{1,2,3}*Department of Economics, Universitas Muhammadiyah Yogyakarta, Indonesia*

⁴*Department of Civil Engineering, Universitas Muhammadiyah Yogyakarta, Indonesia*

*Corresponding Author: Romi.hartarto@umy.ac.id

Abstract

This study examines the relationship between earthquake exposure and housing prices in Sriharjo Village, Imogiri District, Yogyakarta, Indonesia. Using a hedonic pricing framework combined with Geographic Information Systems (GIS)-based spatial analysis, the study analyzes structural, neighborhood, and disaster-related factors associated with residential property values. Primary data were collected from 384 respondents through a household survey and analyzed using ordinary least squares (OLS), with quantile regression employed as a robustness check. The OLS results show that house size, land size, and number of rooms are positively associated with housing prices, while building age is negatively associated with property values. Accessibility also matters, particularly distance to the city center. Most importantly, each additional kilometer from the historical earthquake epicenter is associated with approximately 4.08% higher property values. Quantile regression confirms a positive earthquake-distance coefficient across the conditional housing price distribution, with statistically significant associations from the 0.25 to 0.90 quantiles. GIS analysis further reveals spatial variation in topography, settlement patterns, seismic exposure, and mitigation practices. Overall, the findings provide evidence that seismic exposure is associated with differences in housing values and highlight the importance of integrating disaster risk into housing and spatial planning.

Keywords: hedonic pricing, earthquake, housing prices, spatial analysis, Indonesia

Introduction

Achieving the Sustainable Development Goals (SDGs), particularly Goal 11 on sustainable cities and communities, requires strengthening urban resilience while ensuring access to safe and affordable housing. Rapid urbanization has increased population exposure to environmental hazards, placing growing pressure on land use, infrastructure, and housing systems. Consequently, integrating disaster risk reduction into urban planning has become

increasingly important for minimizing economic losses and promoting sustainable development (United Nations, 2023). Among natural hazards, earthquakes pose substantial threats to residential settlements because of their sudden occurrence, extensive physical damage, and long-term economic consequences.

Indonesia provides an important setting for examining earthquake-related housing vulnerability due to its location along the Pacific Ring of Fire. The country has experienced several destructive earthquakes, including the 2004 Aceh earthquake and tsunami, the 2006 Yogyakarta earthquake, the 2009 West Sumatra earthquake, the 2018 Lombok and Palu earthquakes, and the 2022 Cianjur earthquake. These events have caused substantial casualties, housing destruction, population displacement, and economic losses, highlighting the vulnerability of residential properties to seismic hazards.

The 2006 Yogyakarta earthquake was among the most destructive disasters in the region's recent history, causing more than 5,700 fatalities and extensive damage to residential buildings and infrastructure, particularly in Bantul Regency (BAPPENAS, 2006). Although approximately two decades have passed, earthquake risk remains relevant because the region continues to experience seismic activity. For example, on 20 August 2026, a magnitude 3.5 shallow earthquake occurred near Bantul due to activity along the Opak Fault, with tremors felt in Bantul and Yogyakarta City.¹ These events highlight the persistent exposure of local communities to seismic hazards and the importance of understanding their economic implications for residential property markets.

Beyond physical destruction, earthquake exposure may influence housing prices through perceived safety, expected damage costs, and household location preferences. However, limited empirical evidence is available on how seismic risk is reflected in residential property values in Indonesia, particularly at the household level. Understanding this relationship is important for identifying the economic consequences of earthquake exposure and supporting more informed housing development and disaster risk management.

Against this background, this study investigates the determinants of housing prices in earthquake-prone areas of Yogyakarta, focusing on Sriharjo Village, Imogiri District, Bantul Regency. Specifically, the study addresses two research questions: (1) How are structural, neighborhood, and earthquake-related characteristics associated with residential property values? (2) How are housing characteristics and disaster exposure distributed spatially across the study area? Using primary data from 384 households, the study integrates a hedonic pricing model with Geographic Information Systems (GIS)-based spatial analysis to examine the relationship between seismic exposure and housing prices. The findings are expected to

¹ <https://www.kompas.id/artikel/opak-fault-moves-again-shallow-earthquake-shakes-diy> (Accessed on 16 September 2026)

contribute to understanding disaster-risk capitalization in developing-country housing markets and provide evidence for risk-sensitive housing development and spatial planning.

Literature Review

Natural Disasters and Housing Markets

Natural disasters pose substantial risks to human life, infrastructure, and economic systems, particularly in developing countries where vulnerability and adaptive capacity remain uneven. Beyond direct physical destruction, disasters can generate broader economic disruptions through damaged infrastructure, reduced productivity, population displacement, and long-term impacts on local economic activity (FAO, 2023; Galli et al., 2023). Housing markets are particularly vulnerable because residential properties represent substantial household assets and are directly exposed to environmental hazards.

The economic consequences of earthquakes are evident from several major disasters worldwide. In Asia, notable examples include the 1995 Kobe earthquake in Japan, the 2008 Sichuan earthquake in China, the 2011 Great East Japan earthquake, the 2015 Gorkha earthquake in Nepal, and the 2018 Palu earthquake in Indonesia (Daniell et al., 2012; Goda et al., 2015; Syifa et al., 2019). Beyond Asia, the 1994 Northridge earthquake in the United States, the 2010 Haiti earthquake, and the 2023 Türkiye–Syria earthquakes demonstrate the substantial consequences of seismic hazards for housing, infrastructure, and local communities (Eberhard et al., 2010; World Bank, 2023). These experiences highlight the importance of understanding not only the physical consequences of earthquakes but also their implications for residential property markets.

A growing body of empirical research demonstrates that natural hazards are capitalized into housing prices through perceived risk and anticipated damage costs. Within a hedonic pricing framework, exposure to hazard-prone areas can influence property values by capturing households' willingness to trade off safety against location, accessibility, and other amenities. This relationship has been particularly well documented for flood risk. Bin and Polasky (2004) show that flood hazards affect property values, while Bin and Landry (2013) demonstrate that flood-risk premiums can change following major disaster events as household risk perceptions evolve. Similarly, Beltrán et al. (2018) find that flood risk is reflected in property prices.

Evidence from other hazards, including landslides, wildfires, and coastal risks, further suggests that greater exposure may reduce property values through expected physical losses, mitigation costs, and changes in perceived safety. More recent studies also indicate that disaster and climate risks are increasingly reflected in real estate markets as risk-related information becomes more visible and accessible to households (Bernstein et al., 2019; Bakkensen & Barrage, 2021; Muckenhaupt et al., 2025).

Importantly, the capitalization of disaster risk depends not only on physical exposure but also on households' awareness, previous disaster experience, and perceptions of future risk. Housing markets can therefore provide an economic signal of how households value environmental safety. However, the evidence remains uneven across different types of natural hazards. Compared with the extensive literature on floods and other environmental risks, relatively limited attention has been given to how earthquake risk is reflected in property values, particularly in developing countries.

Earthquake Risk and Spatial Determinants of Housing Prices

A specific strand of the hedonic literature has examined whether earthquake risk is reflected in housing markets. One of the earliest studies is Brookshire et al. (1985), who examined property markets in California and showed that information about earthquake hazards can influence housing values, providing evidence that households incorporate seismic risk into residential decisions. In Japan, Nakagawa et al. (2007) examined housing rents in the Tokyo metropolitan area and found that earthquake risk and building characteristics associated with seismic resistance are reflected in rental values. These studies demonstrate that earthquake risk capitalization is not a new phenomenon and that housing markets can respond to both perceived seismic exposure and structural vulnerability. However, much of the established evidence comes from developed economies with relatively mature property markets, stronger building regulations, and different institutional arrangements for managing disaster risk. Whether similar relationships are observed in developing-country housing markets remains an important empirical question. Housing markets in these settings may differ substantially in construction quality, enforcement of building standards, access to risk information, household financial capacity, and disaster-mitigation practices. Consequently, evidence from developed economies cannot necessarily be generalized to earthquake-prone communities in Indonesia.

Seismic exposure is also inherently spatial. Properties at similar distances from an earthquake source may experience different levels of vulnerability because of variations in geological conditions, topography, structural characteristics, and mitigation measures. Representing earthquake risk using a single or binary indicator may therefore overlook important local heterogeneity (Inagaki & Sadohara, 2019; Kim et al., 2017; Des Rosiers & Lagana, 2024). Integrating hedonic pricing with GIS-based spatial analysis can help address this issue by combining estimates of housing-price relationships with information on the geographic distribution of housing characteristics, topography, mitigation practices, and seismic exposure.

Indonesian Real Estate Literature and Research Gap

Indonesia's residential property market provides an important context for examining the economic consequences of natural hazards. Its location at the convergence of several major

tectonic plates, including the Indo-Australian, Eurasian, and Pacific plates, creates persistent seismic exposure across many residential settlements. The country's experience with major earthquakes highlights the importance of understanding how environmental risks influence housing development, household investment decisions, and residential property values.

Previous studies have examined Indonesian residential property markets from different perspectives. Melpriyanto and Saptutyningsih (2019) applied the hedonic pricing approach to investigate how industrial proximity influences housing prices, demonstrating the importance of environmental characteristics in residential property valuation. Khoirudin and Kurniawan (2023) examined residential property price dynamics in Indonesia using a vector autoregressive approach, providing insights into broader housing market fluctuations. More closely related to disaster risk, Saptutyningsih and Dewanti (2023) employed hedonic pricing to estimate the economic impact of landslide hazards on property values. Together, these studies demonstrate the growing application of economic valuation approaches to Indonesian property markets.

Previous studies also have examined the capitalization of earthquake risk into property values in countries such as the United States and Japan (Murdoch et al., 1993; Naoi et al., 2009). However, evidence from developing-country housing markets remains less established. The contribution of this study therefore does not rest on introducing earthquake-risk capitalization as a new research question, but on providing household-level evidence from Indonesia, where housing markets, building quality, disaster preparedness, and institutional conditions differ from those in more extensively studied developed-country settings. The Yogyakarta context is particularly relevant because the housing stock reflects long-term adjustment following the destructive 2006 earthquake, while households continue to face seismic exposure and differ in their adoption of earthquake-resistant construction practices.

Against this background, the contribution of this study lies primarily in its empirical setting and household-level data rather than in introducing a new hedonic methodology. First, it provides evidence from an earthquake-prone community in Indonesia, complementing previous earthquake-related hedonic studies that have largely focused on developed economies. Second, the household survey captures substantial variation in housing characteristics and earthquake-mitigation practices within a community that experienced the destructive 2006 Yogyakarta earthquake and continues to face seismic exposure. Third, the study combines household-level hedonic estimation with GIS-based spatial analysis, allowing housing values to be examined alongside geographic differences in topography, settlement patterns, proximity to the historical earthquake epicenter, and mitigation practices. This setting provides new evidence on how seismic exposure is associated with residential property values in a developing-country housing market.

Methodology

This study employs a quantitative research approach that integrates the hedonic pricing model (HPM) with Geographic Information Systems (GIS)-based spatial analysis to examine the determinants of residential property values in earthquake-prone areas. The study was conducted in Sriharjo Village, Imogiri District, Bantul Regency, Special Region of Yogyakarta, Indonesia. The study area was purposively selected because of its exposure to seismic hazards, particularly following the 2006 Yogyakarta earthquake, which caused extensive damage to residential infrastructure in Bantul Regency. The area is also characterized by variations in topography, settlement patterns, and proximity to seismic hazards, making it relevant for examining the relationship between disaster exposure and housing prices. Figure 1 shows the location of the study area, including the Special Region of Yogyakarta, Bantul Regency, Imogiri District, Sriharjo Village, and the 2006 earthquake epicenter.

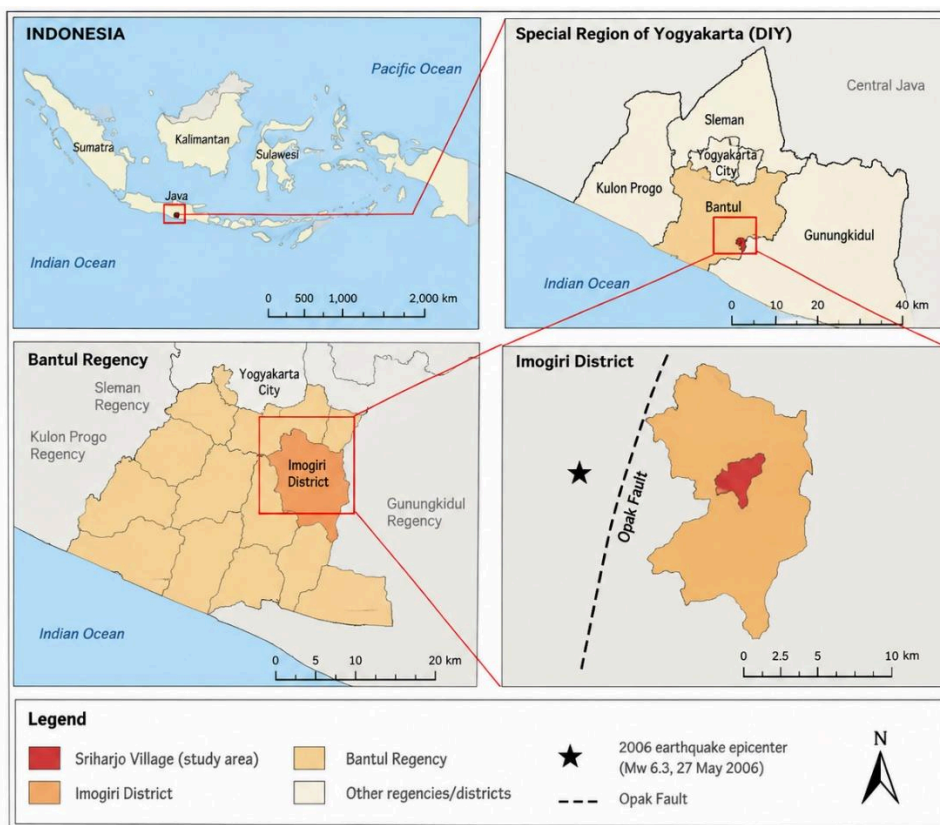


Figure 1. Location of the study area and the 2006 Yogyakarta earthquake epicenter

The study was conducted in Sriharjo Village, Imogiri District, Bantul Regency, Special Region of Yogyakarta, Indonesia. The study area was purposively selected based on its exposure to the destructive 2006 Yogyakarta earthquake and the associated damage and casualties. Primary data were collected between 13 January and 12 February 2024 through a household survey involving 384 respondents.

According to the official Sriharjo Village website, the village comprises 13 hamlets with a total population of 9,309 residents. The sample size was determined using Slovin's formula with a 5% margin of error, resulting in a target sample of 384 respondents. A proportionate stratified random sampling approach was employed to ensure geographical coverage across the village. Each of the 13 hamlets constituted a sampling stratum, with the number of respondents allocated proportionally to its population size. The largest allocations were assigned to Jati and Pelemadu, with 46 respondents each, while Pengkol had the smallest allocation, with 12 respondents. Respondents were randomly selected within each hamlet according to the allocated sample size.

Data collection involved direct field observations, questionnaires, and interviews with selected residents. The research team visited the study locations, distributed questionnaires, and conducted interviews to obtain information on residential property characteristics, accessibility, earthquake exposure, and mitigation practices. The combination of questionnaires, interviews, and field observations provided household-level information for the hedonic pricing analysis and complementary geographical information for GIS-based spatial analysis.

The study received ethical approval from the Faculty of Economics and Business, Universitas Muhammadiyah Yogyakarta (No. 013/A.1-II/FEB/1/2024). Before participation, respondents were informed that their information would be used solely for research purposes and that confidentiality would be maintained in accordance with research ethics. Informed consent was obtained from respondents before data collection. While this sample provides sufficient household-level variation for examining housing characteristics and seismic exposure within the selected earthquake-prone area, it is not intended to be statistically representative of the entire Yogyakarta housing market. Yogyakarta contains substantial variation in urbanization, housing characteristics, land markets, accessibility, and disaster exposure. Accordingly, the findings primarily reflect the local context of Sriharjo Village and should be generalized to the wider Yogyakarta region with caution.

The household survey collected information on residential property values and three groups of explanatory variables: structural characteristics, neighborhood attributes, and environmental factors. The dependent variable is residential property price, measured in Indonesian rupiah (IDR) and transformed into its natural logarithm for econometric estimation. Property values in the sample range from IDR 80 million to IDR 885 million, with an average of approximately IDR 231.6 million.

Structural characteristics include building age, number of rooms, house size, and land size. Building age is measured in years, while the number of rooms represents the total rooms available in each residential property. House size and land size are measured in are, where

one are is equivalent to 100 square meters. These variables capture differences in housing quality, residential space, and land endowments that may influence property values.

Neighborhood characteristics are represented by distances to schools, hospitals, and the city center, measured in kilometers. These variables capture accessibility to public services and economic activities. Distance to the city center is particularly relevant because residential properties located farther from economic centers may experience lower demand due to higher commuting costs and reduced accessibility.

The environmental variable is distance to the earthquake epicenter, measured in kilometers. The earthquake point refers to the recorded epicenter of the 2006 Yogyakarta earthquake at 7.956018° S, 110.360429° E. Each surveyed dwelling was georeferenced using [GPS/device/method], and the distance between the residential location and earthquake epicenter was calculated using [GIS software/method]. Distance is expressed in kilometers, with smaller values indicating greater proximity to the historical epicenter. This variable serves as a proxy for seismic exposure, with properties located closer to the epicenter assumed to face greater exposure to the historical earthquake. However, epicenter distance does not fully capture earthquake vulnerability, which may also depend on geological conditions, building quality, and proximity to active faults. Accordingly, the estimated relationship should be interpreted as an association between epicenter distance and property values rather than a comprehensive measure of seismic risk.

To complement the household survey, secondary spatial data were obtained from relevant geographic sources, including administrative boundaries, topographic characteristics, and earthquake-related geographic information. These data were integrated with the residential locations of surveyed households using GIS. Spatial information was used to examine differences in elevation, slope, settlement distribution, proximity to the earthquake epicenter, and household mitigation practices. The integration of household-level and spatial data provides a more detailed understanding of how residential characteristics and disaster exposure vary across the study area.

To estimate the determinants of housing prices, the study employs a hedonic pricing model, which conceptualizes property values as a function of structural, neighborhood, and environmental attributes (Freeman et al., 2014; Kuminoff et al., 2010). The model is specified in a semi-logarithmic functional form:

$$\ln(P_i) = \beta_0 + \sum_{j=1}^J \beta_j S_{ji} + \sum_{k=1}^K \gamma_k N_{ki} + \delta E_i + \varepsilon_i$$

where P_i represents the residential property price of household i ; S_{ji} represents structural characteristics, including building age, number of rooms, house size, and land size; N_{ki} represents neighborhood characteristics, including distance to schools, hospitals, and the

city center; E_i represents the environmental variable, measured by distance to the earthquake epicenter; and ε_i denotes the error term.

Table 1 presents the definitions and measurement units of the variables used in the hedonic pricing model. The dependent variable is residential property value, expressed in Indonesian rupiah (IDR) and transformed into its natural logarithm for regression analysis. The explanatory variables comprise structural housing characteristics, including building age, number of rooms, house size, and land size, as well as accessibility and earthquake-related factors measured by distances to schools, hospitals, the city center, and the historical earthquake epicenter.

Table 1. Definition and Measurement of Variables

Variable	Definition	Unit
House price	Owner-estimated market value	IDR, natural log
Age of house	Age of residential building at survey date	Years
Number of rooms	Total number of rooms in dwelling	Number
House size	Total building area	Are
Land size	Total land area	Are
Distance to school	Distance from dwelling to nearest/relevant school	Km
Distance to hospital	Distance from dwelling to nearest/relevant hospital	Km
Distance to city center	Distance from dwelling to city center	Km
Distance to earthquake point	Distance from dwelling to the defined 2006 earthquake epicenter	Km

The model is estimated using Ordinary Least Squares (OLS). The semi-logarithmic specification allows the estimated coefficients to be interpreted as approximate percentage differences in housing prices associated with a one-unit change in each explanatory variable, holding other characteristics constant. More precisely, the percentage difference is calculated as $100(e^{\beta} - 1)$. This specification is commonly applied in hedonic pricing studies to estimate the implicit value of housing attributes and environmental characteristics (Kuminoff et al., 2010).

Several diagnostic and robustness tests were conducted to assess the reliability of the empirical results. Multicollinearity was examined using the variance inflation factor (VIF), while heteroskedasticity was assessed using White test. To assess the robustness of the baseline OLS estimates and examine potential heterogeneity across the housing price distribution, this study employs quantile regression. Unlike OLS, which estimates the effects of explanatory variables at the conditional mean of housing prices, quantile regression

estimates their associations at different points of the conditional distribution. This approach is useful because structural characteristics, accessibility, and earthquake exposure may be associated differently with relatively low-, middle-, and high-valued properties. The quantile regression model is specified as:

$$Q_{\tau}(\ln P_i | X_i) = \alpha_{\tau} + \beta_{1\tau}AGE_i + \beta_{2\tau}ROOM_i + \beta_{3\tau}LAND_i + \beta_{4\tau}HOUSE_i + \beta_{5\tau}HOSP_i + \beta_{6\tau}SCHOOL_i + \beta_{7\tau}EARTH_i + \beta_{8\tau}CITY_i + \varepsilon_{i\tau}$$

where $Q_{\tau}(\ln P_i | X_i)$ represents the τ -th conditional quantile of the natural logarithm of housing price given the explanatory variables. The model is estimated at ($\tau = 0.10, 0.25, 0.50, 0.75$, and 0.90), representing different segments of the conditional housing price distribution. AGE_i denotes building age, $ROOM_i$ is the number of rooms, $LAND_i$ is land size, $HOUSE_i$ is house size, $HOSP_i$ and $SCHOOL_i$ represent distances to the hospital and school, respectively, $EARTH_i$ denotes distance from the historical earthquake epicenter, and $CITY_i$ represents distance to the city center. The coefficients $\beta_{j\tau}$ capture the association between each explanatory variable and housing prices at a given conditional quantile.

Particular attention is given to $\beta_{7\tau}$, the coefficient for distance from the earthquake epicenter. Comparing this coefficient across the five quantiles indicates whether the association between seismic exposure and property values is consistent across different segments of the housing market. Similar signs and magnitudes across quantiles would support the robustness of the baseline OLS relationship, whereas variation across quantiles would indicate heterogeneity in the association between earthquake exposure and housing values.

In addition to econometric estimation, GIS-based spatial analysis is conducted to examine the geographic distribution of housing characteristics and disaster exposure. Administrative boundaries, elevation, slope classification, household locations, and earthquake-related geographic information are integrated using spatial overlay techniques. The resulting maps illustrate variations in residential settlement patterns, topographic conditions, proximity to the earthquake epicenter, and mitigation practices. These spatial outputs complement the regression analysis by providing geographic context for interpreting the relationship between seismic exposure and residential property values.

Results and Discussion

The descriptive statistics reported in Table 2 reveal substantial heterogeneity in both housing characteristics and locational attributes across the study area. Housing prices range from IDR 80 million (USD 5,000) to IDR 885 million (USD 55,300), with an average value of approximately IDR 231.6 million (USD 14,500), indicating a wide dispersion in property values. This variation reflects differences in structural quality, land endowments, and exposure to environmental risk. The relatively large standard deviation further suggests that the housing market in the study area is segmented rather than homogeneous, which is

consistent with findings from the hedonic pricing literature emphasizing spatial and structural heterogeneity in property markets (Kuminoff et al., 2010). Such variation is essential for identifying implicit prices in hedonic models and is commonly observed in heterogeneous housing markets, particularly in developing country contexts (Kuminoff et al., 2010; Giglio et al., 2021).

Table 2. Descriptive statistics

Variables	Mean	Std. Dev.	Min	Max
Age of House (years)	25.52	11.73	11	80
Number of Rooms	2.57	0.92	1	6
House Size (are)	1.23	1.11	0.36	11
Land size (are)	4.41	6.95	0.3	81
Distance to school (km)	0.59	0.33	0.05	1.6
Distance to hospital (km)	1.56	1.21	0.08	6
Distance to the city (km)	14.9	1.97	11	18
Distance to earthquake point (km)	2.74	1.43	1	8.1
Property price (million IDR)	231.6	111.3	80	885

Structural attributes also exhibit notable variation. The average building age is approximately 25.5 years, with values ranging from 11 to 80 years, suggesting that the housing stock consists of both relatively new and significantly older properties. The age distribution of the sampled housing stock should not be interpreted as inconsistent with the extensive damage caused by the 2006 earthquake. The reported regional damage does not imply that all dwellings in Sriharjo were destroyed and subsequently rebuilt. The sample contains both pre- and post-earthquake housing, as reflected in building ages ranging from 11 to 80 years. Because the survey does not separately identify whether individual properties were damaged, reconstructed, or repaired following the 2006 earthquake, no such distinction is imposed in the empirical analysis.

The number of rooms averages between 2 and 3, indicating that most houses are modest in size, while house size and land size display considerable dispersion, with land area averaging over 4.4 are but reaching up to 81 are. Such variation implies differences in household wealth and investment capacity, which are typically reflected in housing prices. Accessibility variables further illustrate spatial diversity. The average distance to the city center is approximately 14.9 kilometers, indicating that most properties are in peri-urban or semi-rural

areas. Distances to schools and hospitals also vary substantially, suggesting uneven access to public services. Meanwhile, the average distance to the earthquake epicenter is around 2.7 kilometers, with a range extending up to over 8 kilometers. This variation is particularly relevant for identifying how disaster risk is distributed spatially and subsequently capitalized into property values. Overall, the descriptive statistics confirm that both structural and environmental factors vary considerably across observations, providing sufficient variation for econometric estimation and supporting the application of the hedonic pricing framework.

Table 3 presents the OLS regression results across three specifications. Model 1 includes structural housing characteristics, Model 2 adds neighborhood characteristics, and Model 3 incorporates distance to the earthquake epicenter. The adjusted R-squared increases from 0.247 in Model 1 to 0.547 in Model 2 and 0.553 in Model 3, indicating that neighborhood characteristics substantially improve the model's explanatory power, while the addition of earthquake exposure provides a further improvement. The p-values of the F-statistics are 0.000 across Models 1–3, indicating that the explanatory variables are jointly statistically significant in explaining variations in housing prices. The diagnostic results also indicate no serious multicollinearity or heteroskedasticity concerns. The mean VIF ranges from 1.16 to 1.20, while the heteroskedasticity tests are statistically insignificant across all specifications.

Table 3. OLS Regression Results

Variables	Model 1	Model 2	Model 3
<i>Structural characteristics</i>			
Age of house	-0.009*** (0.002)	-0.005*** (0.001)	-0.005*** (0.001)
Number of rooms	0.094*** (0.023)	0.061*** (0.018)	0.062*** (0.018)
Land size	0.006* (0.003)	0.005** (0.002)	0.006** (0.002)
House size	0.122*** (0.019)	0.107*** (0.015)	0.097*** (0.015)
<i>Neighborhood characteristics</i>			
Distance to hospital		0.058*** (0.014)	0.053*** (0.014)
Distance to school		-0.045 (0.048)	-0.040 (0.047)
Distance to city		-0.128*** (0.008)	-0.120*** (0.008)
<i>Environmental attributes</i>			

Distance to earthquake point		0.040***	
		(0.011)	
Constant	18.987***	20.826***	20.599***
	(0.067)	(0.131)	(0.143)
Observations	384	384	384
Adjusted R-squared	0.247	0.547	0.553
F-stat	31.01	64.84	60.29
p-value (F-stat)	0.000	0.000	0.000
<i>Multicollinearity test</i>			
Mean VIF	1.16	1.19	1.20
<i>Heteroskedasticity test</i>			
Prob > chi2	0.165	0.624	0.876

Dependent variable: log (house price); standard errors are in parentheses;

*Significant at $\alpha = 10\%$; **significant at $\alpha = 5\%$; ***significant at $\alpha = 1\%$.

Structural characteristics remain significant determinants of housing prices across the three specifications. Building age has a consistently negative and statistically significant coefficient, with the Model 3 estimate indicating that each additional year of building age is associated with approximately 0.5% lower property value, holding other factors constant. This relationship may reflect physical depreciation, maintenance requirements, and potential concerns regarding the structural condition of older buildings. In contrast, the number of rooms, land size, and house size are positively associated with housing prices. In the full specification, an additional room is associated with approximately 6.4% higher property value, while larger land and building areas also command price premiums. These findings are consistent with previous evidence that residential markets value greater space, functionality, and housing quality (Malpezzi, 2002; Chau & Chin, 2003; Kuminoff et al., 2010).

Neighborhood characteristics exhibit contrasting associations with housing prices. Distance to the city center has a negative and statistically significant coefficient across Models 2 and 3, indicating that properties located farther from the city center have lower values. This finding is consistent with urban economic theory, whereby proximity to employment, markets, and urban services can increase residential attractiveness by reducing transportation and accessibility costs (Glaeser et al., 2008). Distance to school, however, is not statistically significant, suggesting that school accessibility does not independently explain housing-price variation after other structural and locational characteristics are controlled for.

Distance to hospitals has a positive and statistically significant coefficient in Models 2 and 3. In the full specification, an additional kilometer from a hospital is associated with approximately 5.4% higher housing prices. This result should not necessarily be interpreted

as households preferring poorer access to healthcare. Instead, it may reflect unobserved characteristics associated with hospital locations, including traffic, congestion, noise, population density, or surrounding land uses. The valuation of accessibility may therefore depend on the balance between the benefits of proximity to public facilities and the localized disamenities associated with them (Anderson & West, 2006).

The main variable of interest, distance to the historical earthquake epicenter, is positive and statistically significant at the 1% level in Model 3. The coefficient of 0.040 indicates that each additional kilometer from the epicenter is associated with approximately 4.08% higher housing prices, holding the observed structural and neighborhood characteristics constant. At the sample mean property value of IDR 231.6 million, this corresponds to an illustrative difference of approximately IDR 9.45 million per kilometer. Although this calculation should not be interpreted as a causal willingness-to-pay estimate, it indicates that proximity to the historical earthquake epicenter is associated with an economically meaningful difference in residential property values.

This result is consistent with the earthquake-specific hedonic literature showing that seismic risk can be reflected in housing markets. Brookshire et al. (1985) found that earthquake-risk information affected property values in California, while Nakagawa et al. (2007) documented the capitalization of earthquake risk in housing rents in the Tokyo metropolitan area. More broadly, the finding is consistent with evidence that exposure to natural hazards can be reflected in property values as housing markets incorporate information about potential risks and losses (Bin & Polasky, 2004; Bin & Landry, 2013; Beltrán et al., 2018). The present study extends this evidence to an earthquake-prone residential market in Indonesia. Nevertheless, given the cross-sectional design and the use of distance from the historical epicenter as a proxy for seismic exposure, the coefficient should be interpreted as an association rather than definitive evidence of a causal capitalization effect or household risk aversion.

Table 4 presents the quantile regression estimates at the 0.10, 0.25, 0.50, 0.75, and 0.90 quantiles of the conditional housing price distribution. Overall, the results support the baseline OLS findings while revealing some heterogeneity across housing market segments. House size and distance to the city center exhibit particularly consistent relationships with housing prices across the distribution. House size is positive and statistically significant at all quantiles, with its coefficient generally increasing toward the upper part of the distribution. This suggests that additional residential space is more strongly associated with property values among relatively higher-valued properties. Such heterogeneity is consistent with the hedonic pricing framework, in which the implicit value of individual housing attributes may vary across market segments rather than remaining constant throughout the price distribution (Zietz et al., 2008).

Table 4. Quantile Regression Results

Variables	QR(0.10)	QR(0.25)	QR(0.50)	QR(0.75)	QR(0.90)
Age of house	-0.006*** (0.002)	-0.004** (0.002)	-0.003** (0.002)	-0.004 (0.003)	-0.006* (0.003)
Number of rooms	0.064*** (0.021)	0.061*** (0.022)	0.042** (0.020)	0.052 (0.034)	0.048 (0.039)
Land size	0.001 (0.003)	0.002 (0.003)	0.004* (0.003)	0.009** (0.004)	0.008* (0.005)
House size	0.070*** (0.018)	0.089*** (0.018)	0.126*** (0.017)	0.129*** (0.028)	0.109*** (0.033)
Distance to hospital	0.045*** (0.016)	0.016 (0.017)	0.065*** (0.015)	0.080*** (0.026)	0.079*** (0.030)
Distance to school	0.042 (0.055)	0.006 (0.056)	-0.095* (0.051)	-0.029 (0.087)	-0.003 (0.101)
Distance to city	-0.108*** (0.010)	-0.119*** (0.010)	-0.144*** (0.009)	-0.148*** (0.016)	-0.099*** (0.018)
Distance to earthquake point	0.020 (0.013)	0.031** (0.013)	0.031** (0.012)	0.059*** (0.021)	0.051** (0.024)
Constant	20.152*** (0.167)	20.435*** (0.171)	20.931*** (0.156)	21.003*** (0.267)	20.617*** (0.307)
Observations	384	384	384	384	384

Dependent variable: log (house price); standard errors are in parentheses;

*Significant at $\alpha = 10\%$; **significant at $\alpha = 5\%$; ***significant at $\alpha = 1\%$.

Building age is negatively associated with housing prices across all quantiles, although the coefficient is not statistically significant at the 0.75 quantile. The estimated effect ranges from -0.003 to -0.006 , indicating a broadly consistent depreciation pattern across the housing price distribution. The number of rooms, in contrast, is positive and significant only at the lower three quantiles (0.10–0.50), suggesting that an additional room may be more relevant to the valuation of lower- and middle-priced properties. Land size displays the opposite pattern: its positive association becomes statistically significant from the median upward, with the largest coefficient observed at the 0.75 quantile. These differences reinforce the value of quantile regression for identifying variation in the implicit prices of housing characteristics that may be obscured by conditional-mean estimates (Zietz et al., 2008).

The neighborhood variables also show broadly consistent patterns. Distance to the city center remains negative and statistically significant at all five quantiles, confirming the importance of urban accessibility throughout the housing price distribution. The coefficients range from

–0.099 at the 0.90 quantile to –0.148 at the 0.75 quantile. This result is consistent with urban economic theory, in which improved accessibility to employment and economic activity is capitalized into land and housing values (Glaeser, 2008). Distance to hospitals is generally positive, although it is insignificant at the 0.25 quantile, while distance to schools is statistically insignificant at most quantiles and becomes negative and weakly significant only at the median. Thus, the limited role of school accessibility found in the OLS specification is largely maintained across the housing price distribution.

Most importantly, the quantile estimates provide additional support for the relationship between earthquake exposure and housing prices. The coefficient on distance to the historical earthquake epicenter is positive at every quantile and statistically significant from the 0.25 through the 0.90 quantiles. The coefficient increases from 0.020 at the 0.10 quantile to 0.059 at the 0.75 quantile before declining slightly to 0.051 at the 0.90 quantile. Thus, while the association is not statistically significant among properties at the lowest conditional price quantile, it is evident across the middle and upper parts of the distribution and appears particularly pronounced at the 0.75 quantile. This pattern suggests that the association between seismic exposure and property values is not uniform across housing market segments. One possible interpretation is that seismic exposure is more strongly reflected in the valuation of relatively higher-valued properties, although the quantile estimates alone cannot identify the behavioral mechanism underlying this heterogeneity.

These findings are broadly consistent with previous evidence that earthquake risk can be capitalized into housing markets. Brookshire et al. (1985) showed that information concerning earthquake hazards affected property values in California, while Nakagawa et al. (2007) found that earthquake risk was reflected in housing rents in the Tokyo metropolitan area. The present quantile results extend this literature by showing that, in the Sriharjo context, the positive association between distance from the historical epicenter and property values persists across most of the conditional housing price distribution. Taken together with the OLS results, the quantile estimates therefore strengthen the robustness of the main finding while also indicating meaningful heterogeneity in the magnitude of the earthquake-distance association across housing market segments.

The GIS analysis provides spatial context for the relationships identified in the hedonic models. Figure 2 shows considerable variation in topography across Sriharjo Village. Most surveyed dwellings are concentrated in relatively flat and gently sloping areas, particularly in the western part of the village, while settlements extending eastward are characterized by more varied and steeper terrain. Figure 3 further shows that the 384 surveyed households are distributed across the village administrative area, although residential locations are spatially clustered in accordance with existing settlement patterns. These maps indicate that households face heterogeneous geographical conditions that may influence accessibility, development possibilities, and vulnerability to natural hazards. Such spatial characteristics

are relevant to property valuation because topography and environmental exposure can affect both residential attractiveness and potential disaster losses (Beltrán et al., 2018).

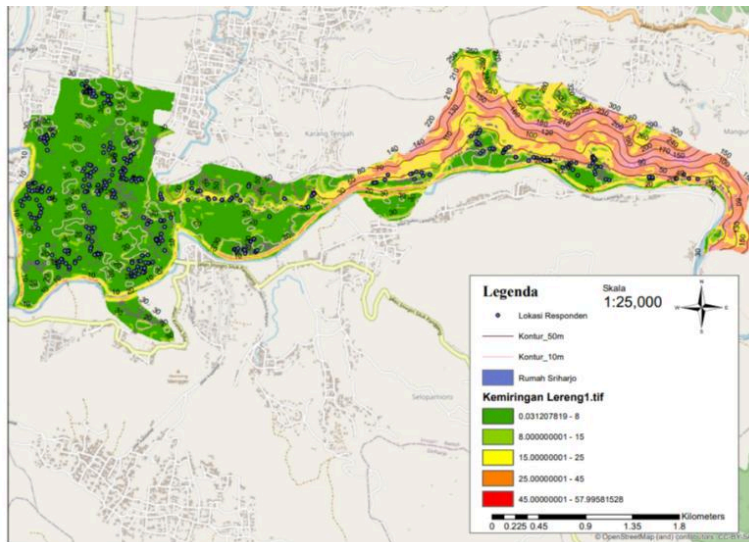


Figure 2. Map of Distribution of Respondents' House Locations Based on Topography

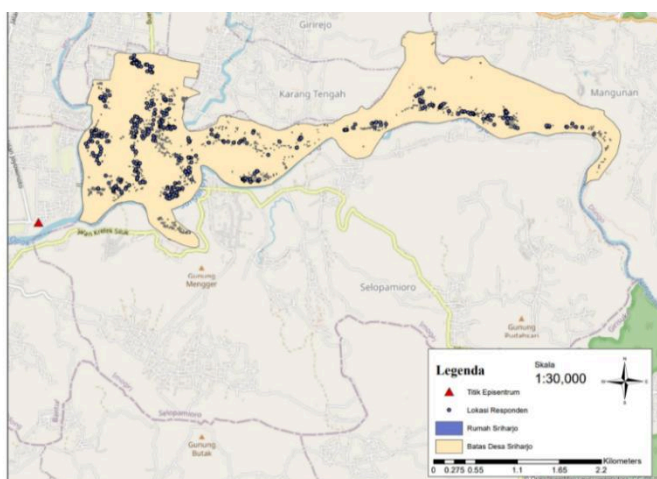


Figure 3. Respondent Location Distribution Map Based on Village Administrative Boundaries

Figure 4 illustrates the spatial distribution of respondents relative to the historical earthquake epicenter. The surveyed properties are located at varying distances from the epicenter, providing the spatial variation underlying the earthquake-distance variable in the hedonic model. Figure 5 adds another dimension by showing the spatial distribution of earthquake-mitigation practices among surveyed households. The map indicates that mitigation practices are not uniformly distributed across the study area, with households reporting such measures located alongside households without them.

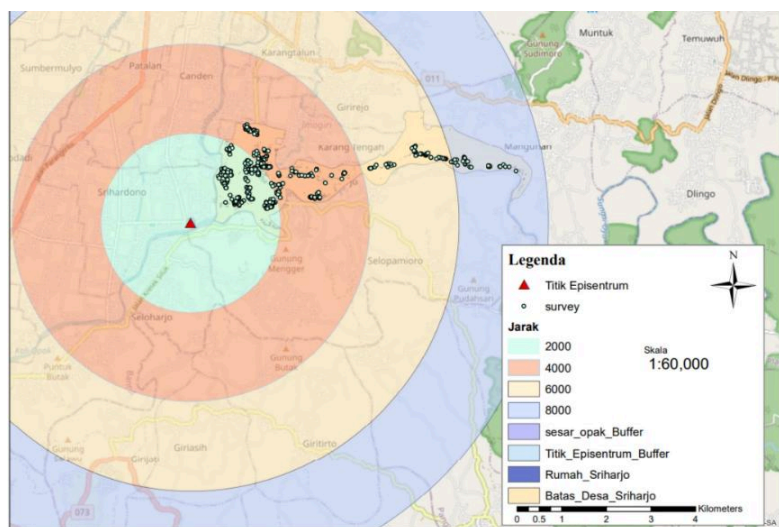


Figure 4. Respondent Location Distribution Map Based on Epicenter Point

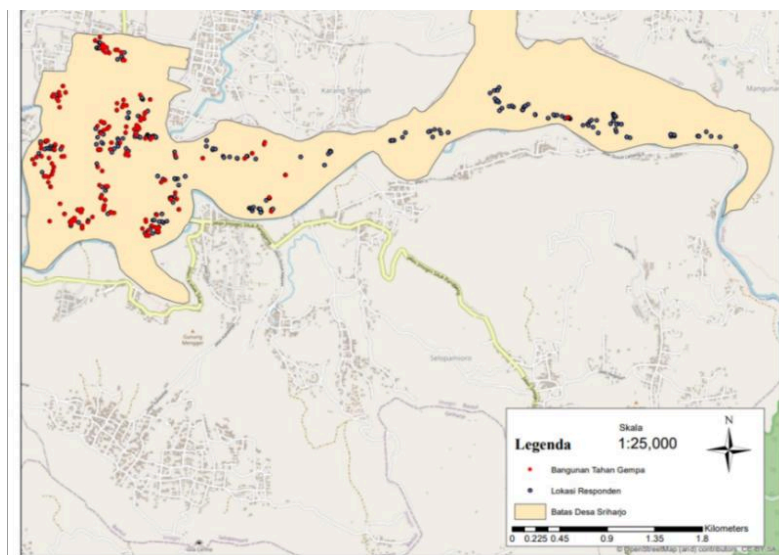


Figure 5. Map of Respondent Location Distribution Based on Mitigation Efforts

The combined spatial and econometric findings therefore have implications for earthquake-risk reduction in Sriharjo. Building age is negatively associated with property values in the OLS model and across most quantiles, while Figure 5 indicates spatial variation in the adoption of mitigation practices. Together, these findings support greater attention to the condition and resilience of the existing housing stock. Local authorities could use spatial information on building characteristics, topography, seismic exposure, and mitigation practices to identify areas where structural assessments and retrofitting support may be most relevant. Technical assistance and affordable financing could complement building standards, particularly for households that face financial constraints in undertaking structural improvements.

The results also suggest that risk-reduction strategies should extend beyond individual dwellings. Hazard information can be integrated into spatial planning and decisions concerning future residential development, while accessible risk maps, disaster education, evacuation planning, and community preparedness can complement structural measures. However, these policy implications should be interpreted cautiously. Distance from the 2006 earthquake epicenter is only a proxy for historical seismic exposure and does not capture other relevant dimensions such as active fault proximity, soil conditions, ground shaking intensity, or detailed structural vulnerability. Future research combining these indicators with information on reconstruction, retrofitting costs, and expected earthquake losses would provide a stronger basis for evaluating geographically targeted risk-reduction strategies.

Conclusions

This study examines housing prices in the earthquake-prone community of Sriharjo Village by combining a hedonic pricing model with GIS-based spatial analysis. The OLS results show that structural and locational characteristics are important determinants of housing values. House size, land size, and number of rooms are positively associated with property values, while building age has a negative association. Greater distance from the city center is associated with lower housing prices, whereas distance to schools is not statistically significant. The main finding is that each additional kilometer from the historical earthquake epicenter is associated with approximately 4.08% higher property values, equivalent to an illustrative IDR9.45 million (USD525) at the sample mean. The quantile regression results reinforce this finding, with earthquake distance remaining positive across the conditional housing price distribution and statistically significant from the 0.25 to 0.90 quantiles, although its magnitude varies across market segments. Together with the GIS evidence of spatial variation in topography, settlement patterns, seismic exposure, and mitigation practices, these results indicate that earthquake-related conditions are meaningfully associated with the local housing market.

The findings highlight the importance of incorporating disaster risk into housing and spatial planning. In addition to enforcing earthquake-resistant standards for new construction, greater attention should be directed toward the existing housing stock, particularly older and potentially vulnerable dwellings. Spatial information on housing characteristics, topography, seismic exposure, and mitigation practices could help local governments prioritize structural assessments, retrofitting assistance, and affordable financing in areas where interventions are most needed. The estimated property-value differences may also provide a useful reference for future evaluations comparing retrofitting costs with expected reductions in earthquake losses and potential protection of household asset values.

Several limitations should be considered. The cross-sectional design does not permit causal interpretation or capture changes in housing prices over time. Distance from the historical

epicenter is only a proxy for seismic exposure and does not incorporate active fault proximity, ground conditions, shaking intensity, or detailed structural vulnerability. Moreover, although GIS is used to characterize spatial patterns, spatial dependence is not explicitly modeled. Future research could combine longitudinal property data with more detailed geological and structural indicators, information on reconstruction and retrofitting costs, and spatial econometric methods to provide a more comprehensive assessment of earthquake risk and housing values.

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