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Insights into earthquake insurance demand in high-risk regions: A case study of Turkey

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ABSTRACT

Over the last three decades, earthquakes have caused approximately USD 1 trillion in economic damage globally. While earthquake insurance can help reduce this damage, there is a significant coverage gap, especially in emerging nations. This research focuses on Turkey, a nation with high vulnerability to seismic activity, to investigate the complex reasons for the low adoption of earthquake insurance. Utilizing a comprehensive set of indicators, including socioeconomic factors, real estate data, and earthquake hazards, this study applies multiple linear regression analysis across various districts. The findings reveal that insurance demand is influenced by peak ground acceleration, average household size, crude birth rate, and percentage of college graduates. While conventional factors such as marriage rate and home price per square have some impact, other expected indicators such as population growth and old age dependency do not show significant influence. By demonstrating how demographic, economic, and seismic risk indicators can predict insurance demand, this research offers fresh insights for policymakers and insurers to enhance their coverage strategies. This approach sheds light on the under-examined dynamics of earthquake insurance demand in high-risk regions and suggests a model that can be adjusted for comparable analyses in other emerging markets.

1. Introduction

Earthquake disasters cause great destructive social and economic impacts. Over the last three decades, more than 800 thousand people have lost their lives and more than 17 million have been homeless due to earthquakes. During this period, the economic damage caused by earthquakes was measured at around USD 1 trillion [1]. Therefore, earthquakes make communities vulnerable to losses in economies with relatively weak financial protection. Earthquake insurance plays a vital role in managing the economic impact of earthquakes. However, there is a significant coverage gap for earthquake-related financial risks worldwide. Since 1990, only 12.9 % of earthquake-related economic losses have been covered by insurance [1]. The loss of approximately USD 913 billion, not covered by insurance, represents a significant burden, especially for developing economies.

Turkey is situated in one of the world's most active earthquake zones, influenced by the Eurasian, African, and Arabian plates. Historical data shows that significant earthquakes happen every 5–6 years and result in devastating impacts on human life and economic development [1]. For instance, the 1999 Izmit and Duzce earthquakes resulted in the deaths of nearly 20,000 people and caused severe economic disruption. More recently, the 2023 Kahramanmaras and Hatay earthquakes caused almost the loss of 50,000

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lives and over US$103 billion worth of damages. The estimated cost of structural damage to residential buildings from the earthquakes was US$54.7 billion, of which only US$1.9 billion was covered by insurance [2,3].

Fig. 1 highlights regions most vulnerable to earthquake hazard in Turkey, underscoring the importance of targeted insurance and risk management strategies. Experts agreed on the high probability of a major earthquake in Istanbul in the near future [4–7]. A major earthquake in Istanbul, which hosts 25 % of Turkey's population and generates 40 % of its GDP, could result in significant casualties and property damage. According to Swiss Re [7], the economic loss from an earthquake of Mw = 7 magnitude in Istanbul, Turkey's largest city, generating more than 40 % of the country's GDP, would reach USD 120 billion. It is estimated that only 20–25 % of the economic loss in such an earthquake would be covered by insurance. That means the state, private sector, and households would bear the remaining bill of approximately 90 billion dollars.

In Turkey, earthquake insurance became mandatory after the Izmit and Duzce earthquakes in 1999 [9]. However, the insurance penetration rate remains low at only 21 %, with significant regional variations, indicating a lack of uniformity in insurance coverage [10,11]. The low coverage of earthquake insurance can be attributed to several factors. Firstly, the mandatory insurance only covers residences within municipal boundaries, excluding homes in villages and buildings that violate construction regulations. Consequently, a significant portion of Turkey's housing stock is not under the scope of mandatory earthquake insurance. Secondly, the basis for calculating insurance amounts is often inaccurate and does not reflect actual construction costs. Lastly, although compulsory insurance is a prerequisite for certain public transactions, there is no systematic enforcement to ensure that policies are renewed, which adversely affects renewal rates and overall coverage consistency.

Previous research conducted in Turkey has shed light on how consumers perceive the risks associated with earthquake [12,13]. However, there remains a significant gap in the understanding of how these perceptions translate into actual insurance demand. This study focuses on the factors that influence the demand for earthquake insurance in Turkey, specifically examining the relationship between earthquake insurance penetration, peak ground acceleration (PGA), and sociodemographic indicators. Earlier research has highlighted PGA's role in earthquake risk assessment and insurance demand [14,15], but insights into the combined effects of PGA and socioeconomic factors on insurance penetration remain limited. This research presents robust empirical evidence that enhances the understanding of the dynamics of insurance demand in high-risk regions like Turkey. It utilizes a comprehensive dataset and a national-scale approach, making its findings valuable for comparative analysis with other emerging markets that face similar insurance coverage gap issues.

The practical implications of this research are summarized as follows:

(i) Turkey is a highly earthquake-prone country and vulnerable to the devastating effects of earthquakes. Unfortunately, the country has a significant coverage gap for earthquake risk. To better manage this risk, it is important to understand the factors that influence people's decisions regarding earthquake insurance in Turkey.
(ii) This study's findings will help insurance companies better understand the factors that drive demand for earthquake insurance in high-risk regions. By using these insights, companies can adjust their product and marketing strategies to better meet consumer needs and expectations.
(iii) This study provides recommendations for policymakers and regulators to address earthquake insurance coverage gap in emerging nations. Policymakers can encourage nationwide coverage of earthquake insurance by implementing incentives. Meanwhile, regulatory authorities can eliminate earthquake insurance system implementation issues by introducing appropriate regulations.

In this context, the study will start with a literature review of the various determinants of earthquake insurance demand. Later, multiple linear regression will be employed to identify determinants of earthquake insurance demand in Turkey. Finally, the research will suggest policy recommendations based on the results obtained.

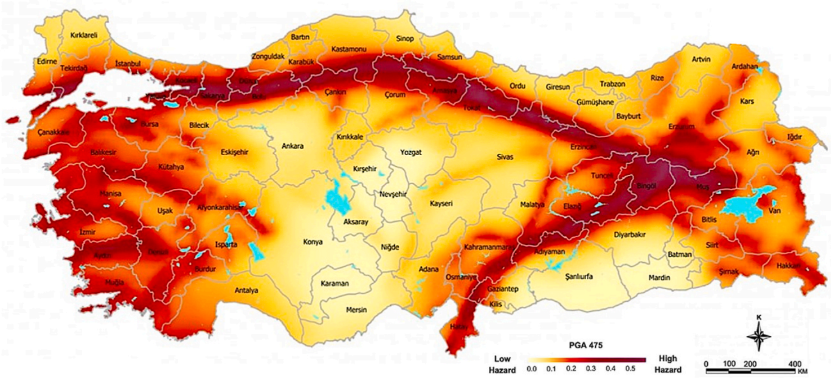

Fig. 1. Seismic hazard map of Turkey.
Source: [8].

2. Literature review

Insurance plays a crucial role in protecting society and the state from the devastating losses caused by natural hazards. Despite its many benefits, there remains a significant challenge in addressing the coverage gap, especially for low-probability, high-severity events [16]. To tackle this challenge, it is important to identify the reasons behind the low insurance penetration [17]. Given its significance, several studies have analyzed the factors that determine disaster risk insurance demand in various regions. These factors typically fall under categories such as socioeconomic, demographic, behavioral, and geographical factors.

Education and income level are key socioeconomic factors that influence insurance demand. Research has shown that individuals with higher education levels tend to seek more earthquake insurance coverage, and higher income levels are also associated with increased insurance consumption. For example, Tian & Yao [18] found statistically significant relationships between education level and demand for earthquake insurance in China. A similar effect is observed in Turkey by Orçanlı et al. [19]. However, some studies show that income level alone may not have a significant effect [20]. The availability and cost of disaster insurance also play a crucial role in coverage levels, with several studies highlighting how affordability significantly impacts demand [21,22].

Various demographic factors, such as age and marital status, have been shown to impact the demand for disaster insurance. A study conducted on Oklahoma's earthquake insurance market between 2011 and 2020 found that older age, male gender, race, and ethnicity were all significant determinants of insurance purchasing decisions [23]. Similarly, a study focusing on Turkey discovered that age, marital status, and gender were associated with earthquake insurance demand [12]. Additionally, Tian & Yao [18] reported that middle-aged individuals have lower demand for earthquake insurance compared to their younger and older counterparts.

The demand for earthquake insurance is influenced by behavioral factors, particularly an individual's perception of risk. According to Zhu et al. [24], ambiguity tolerance and message source influence risk perception and insurance purchasing intentions. Higher ambiguity tolerance individuals feel more risk and are more willing to buy insurance if the risk message is from publicity than that from word-of-mouth. Adigüzel et al. [13] investigated earthquake insurance adoption in Turkey, identifying four non-adopter segments: state reliant positivist, dependers, adversaries, and uninformed loners. This provides insights into how policymakers and insurance companies can differentiate non-adopter segments and develop targeted strategies to stimulate disaster insurance uptake. Zhang & Qian [25] found that risk perception, insurance experience, and government aid significantly influence willingness to pay for earthquake insurance in ethnic minority communities. Those with higher risk perception and more experience tend to desire stronger insurance coverage.

Studies have consistently shown that earthquake insurance demand is closely linked to regional seismic risk [14,15,20,26]. This risk is often represented by PGA, which has been extensively used in numerous studies to model ground motion and examine insurance demand in different regions. For instance, Goda et al. [14] found that despite similar socioeconomic conditions, British Columbia and Quebec had different insurance demands due to the variation in PGA values. Moreover, PGA has been used in models to mitigate the destructive impact of earthquakes, as demonstrated by Giuliani et al. [27] and Ahdika et al. [28].

Upon examining the literature, several key observations emerge:

(i) The severity of earthquake damage and the global gap in insurance coverage highlight the need to understand the complex reasons for the low adoption of earthquake insurance in high-risk regions.

(ii) Previous studies have identified socioeconomic, demographic, and behavioral factors that affect earthquake insurance demand. However, few have examined these factors in combination with seismic risk indicators to evaluate their cumulative influence on insurance penetration.

(iii) Formulating effective strategies is crucial for emerging markets like Turkey, where both economic vulnerability and seismic risk are high, and earthquake insurance coverage is limited.

In light of these observation, this study aims to address this gap by exploring the relationship between earthquake insurance penetration, PGA, and sociodemographic indicators across Turkey. The findings offer valuable insights into the combined effect of earthquake insurance demand dynamics in high-risk regions.

3. Methodology

The current study aims to find a predictive relationship between multiple data sources, which are necessary to determine the fundamental factors that affect the demand for earthquake insurance. The following sections will demonstrate data resources and methods employed in this study.

3.1. Data and variables

This study has included multiple exogenous variables determined based on the literature review to predict demand for earthquake insurance in Turkey. Table 1 shows the details of the selected variables.

In the examination of the demand for earthquake insurance in Turkey, this study has employed a comprehensive dataset that incorporates a range of exogenous variables, which are essential for understanding the regional variations in insurance demand. The primary sources for the data were the Turkish Statistical Institute [10], the Turkish Catastrophe Insurance Pool [11], and Tapusor [37]. The variables extracted include earthquake insurance penetration rates, demographic and socioeconomic indicators such as the percentage of college graduates, marital status proportions, population growth, crude birth rate, old age dependency ratio, and household size. Additionally, real estate data covering home sales rates, price per square meter, and building permit ratios were included to assess their impact on insurance decisions.

Table 1
Details of the variables.

Variable Code	Variable Name	Explanation	Reference
PCG	Percentage of College Graduates	Proportion of the population that has completed university education, indicating the educational level.	[18,25]
AHS	Average Household Size	Average number of people living within a single household, reflecting family size.	[19,29]
OAD	Old Age Dependency Ratio	Proportion of people older than 65 compared to the working-age population, highlighting old age dependency.	[30,31]
CBR	Crude Birth Rate	Number of live births per 1,000 people, measuring population growth from births.	[32]
PMP	Percentage of Married Population	Proportion of the population that is married, serving as an indicator for social structure.	[12,29,33]
PGR	Population Growth Rate	Percentage increase in the population, reflecting demographic changes.	[22,34]
HSR	Home Sales Rate	Frequency of home sales, reflecting the real estate activity.	[35]
BPR	Building Permit Ratio	Ratio of building permits issued to the total number of buildings, indicating construction activity and development in the area.	[36]
HPM	Home Price per Square Meter	Average cost of real estate per square meter, used to gauge wealth and cost of living.	[22]
PGA	Peak Ground Acceleration 475	Maximum ground acceleration expected with a 475-year return period, used as a key measure in seismic risk assessment to determine potential earthquake impact on structures.	[14,15]

The peak ground acceleration (PGA) indicator, which represents earthquake hazard, was calculated based on data from the 2018 Turkey Earthquake Hazard Map and Building Earthquake Regulation [8]. The PGA 475 values, as given in the regulation, are based on latitude and longitude coordinates. Due to the lack of district-specific acceleration values, an expert geomatics engineer created a model for each district by assuming linear change and matching the values with district boundaries. Fixed spaced grids were generated, and an interpolation method was used to assign values to each grid. For districts with multiple risk values and large areas, these values were averaged to obtain a total risk value for each district.

All data sources are publicly accessible or can be obtained upon request from the respective institutions. The dataset includes information from all 976 districts in Turkey for the year 2021, providing a comprehensive overview of the entire country. Additionally, a sample dataset is included in the appendix to illustrate the structure and content of the data.

3.2. Research design

This study was designed to examine which variable(s) adequately predict the demand for earthquake insurance in Turkey. Hence, many variables were helpful in examining this relationship and multiple linear regression analysis (MLR) was appropriate for the sake of the current study. MLR could be classified as a useful extension of simple linear regression under the existence of multiple predictors on one dependent variable [38]. Consequently, MLR was used to examine associations between the simultaneously exogenous variables above and earthquake insurance demand. Linear regression has been widely used in similar studies to model insurance demand, particularly in contexts involving complex predictor interactions. For instance, Athavale & Avila [26], Tian & Yao [18], and Lin [15] employed linear regression to explore relationships between variables and insurance demand, highlighting its relevance in this research field.

The regression model used is defined as follows:

$$EID = \beta0+\beta1(PCG)+\beta2(AHS)+\beta3(OAD)+\beta4(CBR)+\beta5(PMP)+\beta6(PGR)+\beta7(BPR)+\beta8(HPM)+\beta9(PGA)+\varepsilon$$

Here, EID represents the estimated value of the dependent variable (earthquake insurance demand). Each β (from $\beta1$ to $\beta9$) represents the estimated regression coefficients for each independent variable, which quantify the expected change in EID for a one-unit change in the respective independent variable, holding all other variables constant. The $\beta0$ represents the intercept, which is the expected value of EID when all the independent variables are equal to zero. Lastly, ε represents the error term, which accounts for the variability in EID not explained by the independent variables.

The utilization of linear relationships within a complex analytical framework and the use of MLR in this study are substantiated by the nature of the data and the research objectives. The primary aim of this model is to identify predictors that significantly influence the demand for earthquake insurance in Turkey. Linear regression is particularly advantageous in scenarios where multiple variables potentially affect a single dependent variable. This relationship permits an assessment of the individual contribution of each variable while controlling for others, thus providing a clear, quantifiable insight into how each predictor impacts the dependent variable [39].

The selection of MLR was predicated on its capacity to handle multiple predictors simultaneously, which is crucial given the array of variables considered in this study. These variables, selected based on their relevance to insurance demand, include demographic, economic, and geographical factors. The data set was meticulously formed from reliable sources, ensuring a comprehensive representation of the variables across the districts of Turkey. The methodology involved initially collating data, followed by rigorous preprocessing to ensure compatibility and accuracy before analysis. This preprocessing stage was crucial to address any issues of multicollinearity and to verify the integrity of the data.

Subsequently, the analysis proceeded through several stages. Initially, a descriptive statistical analysis was conducted to provide an overview of the data distributions and central tendencies. This was followed by the application of MLR to explore the relationships between the variables. The MLR model's adequacy was evaluated using standard diagnostic tests to assess the assumptions of linear regression, including linearity, independence, homoscedasticity, and normality of residuals. The final stage involved interpreting the coefficients of the regression model to draw conclusions about the factors influencing earthquake insurance demand.

This methodological approach ensures that the study remains transparent and reproducible, with clear delineations of each analytical phase to facilitate validation and further research by peers in the field. Such a structured approach not only addresses the initial query but also reinforces the reliability of the findings, thereby enhancing the scientific contribution of the study to the understanding of insurance demand in high-risk regions.

4. Results

As discussed in the preceding section, MLR analysis was utilized to ascertain the variables influencing earthquake insurance demand in Turkey. Before conducting a rigorous analysis, the data was assessed for various assumptions, including normality, identification of outliers, assessment of collinearity, and the necessity for additional predictors and homoscedasticity.

For homoscedasticity, a Breusch-Pagan Test [40] was used to determine if residual variances were equal across all fitted values. Using this test, the null hypothesis was retained as a possibility and the alternative hypothesis that claims at least one of the residual variances is different than others was rejected. Results yielded a Chi-square = 0.149, Df = 1, p = 0.698. As the p-value was greater than 0.05, the null hypothesis was rejected, which meant the homoscedasticity assumption was met.

For independence of residuals assumption, a Durbin Watson test [41] was conducted to see existence of autocorrelation between the errors. The autocorrelation was calculated as −0.01 whereas D-W Statistic was 2.021 and associated p-value was 0.728. These results showed that there was no autocorrelation between the residuals.

To check for normality, the Q-Q plot of the normality was investigated. This method compares theoretical and empirical quantiles to see if there is any departure from the linear relationships. As it could easily be seen (Fig. 2), although there are extreme values, residuals follow approximately a normal distribution, so there was no violation of the normality assumption.

In assessing the normality of residuals for the MLR model, a fundamental assumption of the linear regression analysis, the residual plot provides an essential diagnostic tool [42]. The residual distribution depicted in Fig. 3, obtained from the model, reveals a distribution that closely approximates a normal curve with a marginal skewness, indicating a slight deviation from the ideal normal distribution. This slight skew in the residual distribution suggests that while the assumption of normality is not strictly met, the deviation is minimal and may not significantly impact the validity of the regression model's inferences.

Consequently, Variance Inflation Factor calculations were used to determine if there was a multicollinearity in the model. For this quantity, if VIF is close to 1, there is no multicollinearity; if it falls between 1 and 5, there is a moderate collinearity, which signs for a possible assumption violation and if VIF is greater than 5, then there is a definite assumption violation. For the model, VIFs ranged between 1.005 and 1.182, which showed there is no multicollinearity for the model.

Upon scrutinizing the assumptions, a significant correlation (rbmr, hsr = 0.89) was identified between the building permit ratio and the home sales rate. Subsequent detailed analysis revealed that the correlation between the building permit ratio and earthquake insurance demand was stronger than the home sales rate. Therefore, the building permit ratio was chosen as the primary variable to

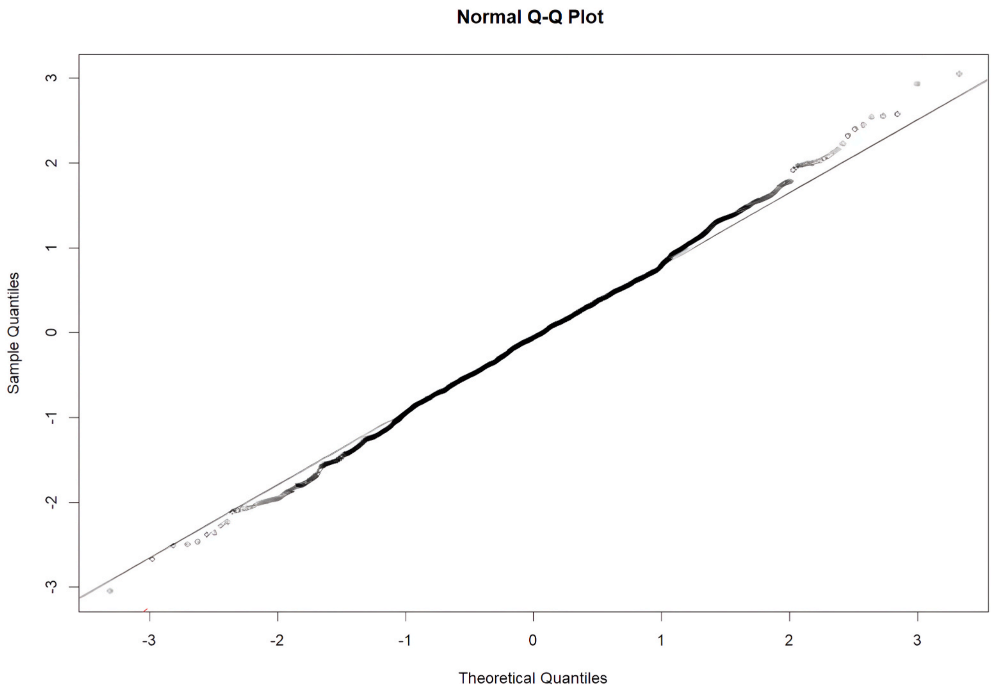

Fig. 2. Normal Q-Q plot of fitted values.

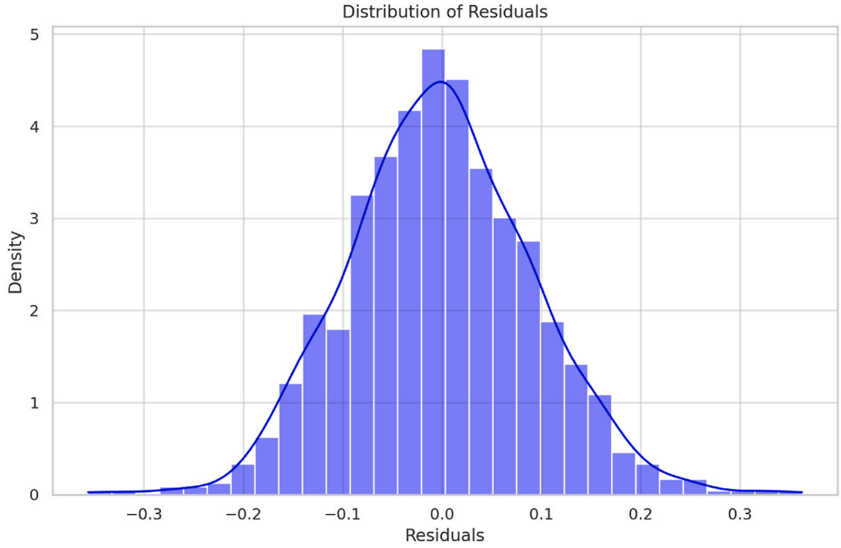

Fig. 3. Residual distribution plot of fitted values.

keep in the model. Besides this issue, the average household size did have some outliers within the data. Rather than losing a predictor, a log transformation was applied to this variable to make it as normal as possible. After taking the log transformation of this variable, it became approximately normally distributed. The last correction was made to the home price per square meter because the scale was within the thousands range. It was necessary to take it to the same scale with the dependent variable to prevent inflation in the regression coefficient. To do that, all values were divided by 1000 and used as that.

After conducting the necessary assumptions, a summary of the descriptive statistics was created for use in MLR, as presented in Table 2.

The overall earthquake insurance penetration of the sample was 20.8 %. On a regional basis, the provinces with the highest insurance penetration rates were Tekirdag, Yalova, and Istanbul. Conversely, the provinces with the lowest insurance rates were Hakkari, Gumushane, and Mus. The difference in insurance penetration between the provinces with high and low rates varies up to 700 %. A quick look at the district level data shows that this difference could increase even more. The differences in insurance penetration among the regions also appeared in socioeconomic variables. Home price per square meter, old age dependency ratio, and average household size were the variables with the highest standard deviation across districts.

Initially, a hierarchical multilevel linear modeling was assumed to be an appropriate analysis method because of the nested structure of data. However, to determine whether MLP or multilevel modeling was more appropriate for the dataset, the Akaike Information Criterion (AIC) was used as a measure of model fit and parsimony. The MLR model yielded an AIC value of 302.5, which was significantly lower than the AIC of 312.3 observed for the multilevel model, suggesting a better fit to the data with fewer parameters. Additionally, the significance of the predictors in the MLR model was confirmed by p-values less than 0.05, indicating robust statistical significance. This evidence strongly supports the selection of MLR for analyzing the data, as it provides a more efficient model without the complexity required by multilevel modeling. Thus, based on the AIC and p-value criteria, MLR was deemed the most appropriate analytical approach for the research objectives.

After running the first round of MLR, the following β coefficients and statistics have been obtained (see Table 3):

R^2 for the model was 0.597, while adjusted R^2 was 0.5648, which yielded an adequate model fit for MLR analysis. When all independent variables were examined one by one, three were nonsignificant to predict earthquake insurance demand in Turkey. These variables were OAD, PGR, and BPR. Other than these three variables, the remaining variables significantly predicted earthquake insurance demand in Turkey. To further analyze the model with only significant predictors, a second wave of MLR analysis was conducted. The following β weights and statistics were obtained in the second wave of analysis (see Table 4):

Table 2
Descriptive statistics.

Variable	Min	Max	Mean	SD
PCG	0.02	0.46	0.12	0.05
AHS	0.30	0.85	0.48	0.08
OAD	0.03	0.74	0.24	0.13
CBR	0.03	0.44	0.10	0.05
PMP	0.28	0.65	0.50	0.06
PGR	−0.21	0.30	−0.02	0.03
BPR	0.03	0.12	0.01	0.01
HPM	0.07	2.52	0.28	0.27
PGA	0.07	0.72	0.31	0.13

Table 3
MLR results for model-1.

Variable	β	Std Error	T value	Significance Level	Significant?
PCG	2.456	0.223	2.23	0.026	sig
AHS	−3.952	0.269	−2.31	0.021	sig
OAD	0.768	0.124	0.62	0.535	non-sig
CBR	−2.259	0.412	−2.18	0.029	sig
PMP	−1.706	0.302	−2.01	0.044	sig
PGR	−0.115	0.299	−0.21	0.083	non-sig
BPR	0.568	0.773	0.47	0.631	non-sig
HPM	1.693	0.33	2.00	0.044	sig
PGA	7.458	0.653	3.18	0.001	sig

Table 4
MLR results for model-2.

Variable	β	Std Error	T value	Significance Level	Significant?
PCG	2.545	0.199	2.29	0.023	sig
AHS	−4.511	0.248	−2.36	0.018	sig
CBR	−2.112	0.412	−2.11	0.035	sig
PMP	−1.731	0.291	−1.97	0.048	sig
HPM	1.465	0.329	1.94	0.052	sig
PGA	7.749	0.652	2.97	0.003	sig

In MLR analysis, the beta coefficients represent the influence of each variable on the dependent variable when other factors are held constant. The coefficient for PCG is 2.545, suggesting that an increase in PCG by one unit is associated with an increase of approximately 2.545 units in the dependent variable, indicating a positive relationship. Conversely, AHS shows a beta coefficient of −4.511, which implies that an increase in AHS leads to a decrease in the dependent variable by about 4.511 units, highlighting a strong negative impact. Similarly, CBR and PMP, with coefficients of −2.112 and −1.731, respectively, also negatively influence the dependent variable, though their impacts are slightly less pronounced compared to AHS.

On the other hand, HPM presents a positive beta coefficient of 1.465, suggesting a beneficial effect on the dependent variable with each unit increase in HPM. The most substantial effect among the variables comes from PGA, with a beta coefficient of 7.749. This indicates that PGA has the strongest positive influence on the dependent variable, where an increase in PGA by one unit boosts the dependent variable by approximately 7.749 units. These coefficients collectively provide a comprehensive view of how each variable contributes to the model, with PGA, PCG, and HPM enhancing the outcome, while AHS, CBR, and PMP detract from it, each to varying extents.

Multiple R^2 for the current model was 0.562 and adjusted R^2 was 0.548, showing an acceptable model fit. The R-squared value of approximately 0.562 and the adjusted R-squared of 0.548 in the current model indicate a respectable level of explanatory power concerning the dependent variable, which in this case is earthquake insurance demand. The value of 0.562 for R-squared suggests that approximately 56.2 % of the variance in earthquake insurance demand can be explained by the independent variables included in the model. This is a significant proportion, reflecting a substantial explanatory capability, especially in social science research where higher complexities often prevent models from achieving very high R-squared values [43].

Moreover, the adjusted R-squared value, which adjusts for the number of predictors in the model, is very close to the R-squared value, at 0.548. This proximity indicates that the model does not suffer substantially from the inclusion of extraneous predictors. The loss of only 3 % of the explained variance after removing non-significant predictors confirms that these predictors were not contributing significantly to the explanation of the dependent variable. This efficient pruning enhances the model's generalizability and avoids the risk of overfitting, thereby making it more robust for practical applications and theoretical interpretations. These metrics collectively justify the model's fit and affirm the decisions made in the model construction and variable selection phases.

5. Discussion

In recent years, disasters due to natural hazards have caused extensive social and economic damage worldwide. Earthquakes, in particular, pose a significant risk due to their potential for widespread loss of life and financial devastation. Unfortunately, many countries located in earthquake-prone regions are developing or underdeveloped economies. Moreover, the lack of earthquake insurance coverage in these countries exacerbates the risk. Turkey, which is prone to earthquakes, has a low rate of insurance coverage. The catastrophic earthquakes that hit Kahramanmaras and Hatay in 2023 resulted in substantial economic losses that affected Turkey's overall economy. Due to limited insurance coverage, the majority of these financial losses were borne by the state, private sector, and households [3]. With the potential for a catastrophic earthquake in Istanbul, Turkey's largest city, it is vital to explore the factors that influence demand for earthquake insurance and to implement policies that increase coverage.

The purpose of this research was to gain insight into the key factors driving earthquake insurance demand in Turkey. By analyzing various indicators including socioeconomic factors, real estate data, and an earthquake hazard, the purpose of the study was to identify the most influential determinants of insurance coverage nationwide. Utilizing MLR to explore relationships between dependent and independent variables, the findings revealed that peak ground acceleration, average household size, crude birth rate, and the percentage of college graduates are the most significant factors impacting earthquake insurance penetration in Turkey. While variables like the percentage of the married population and home price per square meter also contributed, their influence was relatively minor. No meaningful correlation was observed between the population growth rate, old-age dependency ratio, building permit ratio, and earthquake insurance penetration.

Peak ground acceleration is a term used to describe the maximum level of ground motion anticipated during an earthquake in a specific area. In regions with high peak ground acceleration, earthquakes can cause more damage as the seismic force exerted on buildings increases [44]. The close link between earthquake risk and the demand for insurance implies that people tend to react to the threat and risks of earthquakes. Consequently, in areas with higher earthquake risks, individuals tend to be more aware of the hazards and are more likely to demand insurance coverage [15,26]. However, despite the high levels of earthquake risk in some regions, there are still coverage gaps and insurance penetration rates remain below 25 %. This indicates that earthquake risk alone is insufficient to increase insurance adoption rates. Therefore, policymakers and practitioners must do more to educate people on the importance of insurance as a protective measure against earthquake damage and the need for insurance coverage more effectively.

The relationship between demographic indicators and insurance demand suggests a trade-off between individuals' risk perception and financial priorities [18]. When households have larger sizes or higher birth rates, they tend to allocate fewer resources toward insurance protection due to their increased financial needs for daily living. As a result, short-term and immediate financial concerns tend to take precedence over long-term risk protection gains. Due to this myopic tendency of individuals, the demand for insurance is often limited by financial pressures and urgent needs [45]. However, a higher level of education has a positive impact on the demand for earthquake insurance, indicating that education supports risk awareness and financial literacy. As individuals become more educated, they tend to better comprehend the long-term destructive effects of earthquakes and the importance of insurance protection [25]. To address this issue, governments should consider implementing financial incentives to increase insurance coverage rates among groups with lower socioeconomic development. Additionally, insurers should work with the public sector to provide training activities that effectively communicate the scope and significance of earthquake insurance.

Contrary to the existing literature, the study reveals that there is no correlation between various indicators, such as population growth rate, building permit rate, and insurance demand [34,30]. This suggests that only focusing on economic development is not enough to provide financial protection against earthquake risk. Rather, a more comprehensive policy approach is required. In regions with high earthquake risk, addressing insurance coverage gaps must be a part of housing and urban transformation policies. Despite the implementation of compulsory earthquake insurance in Turkey, the limited penetration rates show that governments have a greater responsibility in establishing the habit of purchasing insurance. Increasing population and rebuilding infrastructure may offer an opportunity to boost earthquake insurance rates, but a more holistic approach is needed to achieve sustainable development.

6. Conclusions

The study's finding that peak ground acceleration plays the most important role in earthquake insurance adoption underlines the critical link between seismic risk and insurance demand. Despite the acceptance of risk, insurance penetration remains low, pointing to an important coverage gap that policy interventions need to address. The findings also reveal that financial pressures and short-term needs overshadow the perceived benefits of insurance, especially in households with larger sizes or higher birth rates. This suggests a need for targeted financial education that emphasizes the long-term benefits of earthquake insurance. The lack of correlation between economic development indicators and insurance demand emphasizes that economic progress alone does not necessarily translate into better financial protection against earthquakes. Therefore, comprehensive policy approaches that integrate insurance with urban development policies are required.

In conclusion, this study provides valuable insights into the determinants of earthquake insurance demand in Turkey and offers practical implications for enhancing coverage in other earthquake-prone regions. However, it is important to note that the study has some limitations. First, it focuses solely on Turkey, so while certain findings may apply to other countries with similar risk profiles and socioeconomic development, cultural differences could impact results. Furthermore, the study primarily examines social trends and does not consider individual behavior towards insurance demand. To better understand regional, social, and individual patterns, future research could conduct comparative studies across different earthquake-prone regions.

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CRediT authorship contribution statement

Hasan Meral: Writing – review & editing, Writing – original draft, Conceptualization. **Behlul Ersoy:** Writing – original draft, Conceptualization. **Ismail Dilek:** Writing – review & editing, Methodology, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

We have uploaded the data to Mendeley. Doi: 10.17632/rw84cshczg.1.

Appendix

Table 5
Sample data for district-level variables in Turkey.

Earthquake Insurance Penetration	Percentage of College Graduates	Average Household Size	Old Age Dependency Ratio	Crude Birth Rate	Percentage of Married Population	Population Growth Rate	Home Sales	Building Permit Ratio	Home Price per Square Meter	Peak Ground Acceleration
0,052	0.087	3.519	0.085	0.010	0.515	−0.090	1,208	0.006	1,460	0.203
0.160	0.114	3.607	0.105	0.014	0.462	−0.075	7,956	0.000	2,246	0.285
0.005	0.284	2.668	0.190	0.009	0.484	0.069	208	0.009	4,315	0.186
0.138	0.079	2.985	0.164	0.008	0.533	−0.285	474	0.005	2,139	0.209
0.080	0.083	3.397	0.123	0.012	0.478	−0.140	1,209	0.010	2,309	0.257
0.418	0.088	3.231	0.114	0.012	0.520	−0.045	303	0.008	2,300	0.188
0.195	0.083	2.757	0.158	0.016	0.469	−0.147	6,385	0.000	3,297	0.244
0.282	0.133	2.943	0.167	0.010	0.485	−0.049	8,109	0.010	2,519	0.264
0.009	0.111	2.951	0.182	0.011	0.541	0.038	446	0.015	3,003	0.202
5.871	0.084	3.030	0.137	0.009	0.503	−0.371	1,731	0.001	2,613	0.233
0.005	0.121	4.012	0.077	0.015	0.461	0.707	1,275	0.031	2,996	0.247
0.005	0.130	2.961	0.163	0.014	0.439	−0.045	808	0.002	3,187	0.213
1.442	0.091	3.302	0.120	0.012	0.512	−0.182	1,841	0.010		0.177
2.836	0.101	3.553	0.051	0.010	0.467	0.244	5,389	0.005	3,299	0.305
0.006	0.086	3.238	0.097	0.017	0.433	−0.123	386	0.003	2,963	0.251
0.103	0.093	4.014	0.067	0.015	0.468	−0.068	129	0.031	2,067	0.257
0.023	0.120	3.547	0.109	0.016	0.487	−0.153	331	0.000	2,277	0.552
0.562	0.043	3.926	0.109	0.020	0.432	−0.486	478	0.004		0.379
0.146	0.112	3.664	0.148	0.013	0.489	−0.011	1,214	0.037	2,355	0.483
0.377	0.083	3.315	0.116	0.021	0.425	0.071	6,487	0.006	2,535	0.264
0.003	0.150	4.369	0.069	0.017	0.446	0.050	600	0.027	3,100	0.296
0.030	0.090	3.410	0.094	0.021	0.441	−0.649	20	0.038		0.179
0.019	0.061	4.637	0.118	0.019	0.444	−0.238	22	0.004		0.542
0.207	0.074	3.034	0.137	0.014	0.479	−0.261	898	0.002		0.470
0.084	0.073	3.218	0.074	0.012	0.539	−0.085	1,541	0.007		0.353
0.087	0.073	2.886	0.123	0.014	0.496	0.149	80	0.003	2,632	0.218
0.088	0.135	2.755	0.155	0.011	0.506	0.178	40	0.011	2,395	0.281
0.042	0.104	3.052	0.153	0.009	0.533	−0.128	6,464	0.006	2,215	0.314
0.858	0.032	2.834	0.157	0.019	0.506	−0.157	302	0.002		0.326
0.506	0.104	2.807	0.158	0.012	0.546	−0.029	32	0.015	2,487	0.322
0.007	0.111	3.228	0.120	0.011	0.537	−0.029	237	0.011	2,800	0.291
0.006	0.081	2.945	0.159	0.009	0.509	0.687	2,407	0.023	3,469	0.197
0.023	0.082	2.971	0.164	0.008	0.542	−0.177	1,711	0.031		0.304
4.490	0.060	2.607	0.246	0.007	0.565	−0.230	373	0.002		0.327
0.190	0.053	3.184	0.157	0.013	0.531	−0.127	27	0.004	2,019	0.280
0.070	0.071	2.781	0.185	0.017	0.511	−0.018	1,105	0.006	1,281	0.247
0.479	0.066	2.715	0.158	0.008	0.590	−0.488	10,883	0.002		0.292
0.010	0.158	3.902	0.083	0.013	0.479	0.206	410	0.015	3,140	0.331
0.007	0.104	4.998	0.077	0.009	0.536	−0.008	836	0.011	3,573	0.303
0.059	0.050	2.841	0.181	0.011	0.563	−0.154	26,229	0.002	1,311	0.381
0.041	0.077	2.999	0.195	0.011	0.545	−0.104	1,913	0.003	2,599	0.266
0.099	0.098	2.189	0.312	0.007	0.584	−0.165	832	0.008	1,366	0.293
0.016	0.058	4.335	0.048	0.023	0.381	−0.366	16,930	0.005		0.280
0.017	0.068	4.467	0.051	0.021	0.386	−0.109	3,870	0.017	1,493	0.308
0.051	0.063	4.442	0.054	0.020	0.414	−0.242	192	0.000	1,171	0.301
0.093	0.046	3.787	0.072	0.024	0.370	−0.458	131	0.020		0.240
0.600	0.115	4.332	0.060	0.020	0.398	0.005	1,306	0.012	1,709	0.243
0.070	0.056	4.717	0.045	0.026	0.383	−0.391	23,170	0.007	1,868	0.305
0.027	0.058	4.110	0.062	0.020	0.391	−0.359	1,102	–		0.274

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