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## ESTIMATION OF EARTHQUAKE INSURANCE PREMIUM RATES: TURKISH CATASTROPHE INSURANCE POOL CASE

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**ABSTRACT.** Earthquakes are the natural catastrophes which have the highest unpredictability; destructive earthquakes appear less frequently in time and space. However, the financial impact of such earthquakes on human lives and economies is disastrous. The prediction on the occurrence of an earthquake in time, magnitude and location is expressed in terms of their joint probabilities. The estimation on the economic losses mainly depend on the properties of the structure. The variability in these variables makes it difficult to collect enough historical information for a precise loss estimation and, hence, for determining a realistic insurance premium. This paper questions how much load should be added to the earthquake insurance premiums which incorporate the influence of the factors being ignored due to the loss of the information. Bayesian regression emphasizing the information needed in optimal premium valuation conditional to the parameter estimates, is employed. The implementation of the proposed method is done for the parameter estimation in Turkish Catastrophe Insurance Pool premiums which aims to yield a limited earthquake coverage in a compulsory insurance scheme.

### 1. INTRODUCTION

The magnitude of the losses resulted from earthquakes compared to other natural catastrophes is unpredictable. The occurrence of an earthquake is random in time, space and magnitude whose consequences are destructive and costly when, especially, the construction quality and environmental conditions are under required standards. One of the common risk transfer methods in natural catastrophes is insurance. The interest on insuring a natural catastrophe, such as earthquake lies on the low frequency on its appearance over a certain period. Due to its economic loss magnitude, the premium required for covering such risk is relatively high, especially for the commercial and industrial objects. However, insurance itself will not be sustainable to cover the losses when such a destructive catastrophe hits a certain region. For this reason, a mechanism, international reinsurance market, generates

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the security to share the risk. Reinsurance is a very important instrument that helps decreasing the risk exposure. The risk and capital management of the primary insurance company are supported by reinsurance and it contributes to enhancing the size and competitiveness of insurance markets [13, 16]. Most common reinsurance contracts include terms such that the amount of risk transferred is limited which are finite reinsurance. By finite reinsurance, additional capital and capacity is brought to insurance markets. The main concern of insurance and reinsurance companies is how to estimate the correct premium for a certain object located in a certain region whose earthquake history is poorly kept or insufficient to make unbiased forecasts. Even though the earthquake catalogues and historical losses exist in literature, the diversity in the characteristics on the losses does not allow to set a robust modeling. The main components of determining the (re)insurance premiums mainly is based on historical losses. However, the type and the amount of the losses show many variations which may or may not be appearing in the next occurrence. Therefore, the premium which is determined based on the last years' observations may mislead the evaluation and calculation of the correct premium.

The aim of this study is to determine how much load should be given to each component having contribution to the loss in determining the premium under incomplete information. The methodology suggests the implementation of Bayesian regression and Gibbs-sampler in case of restricted information on the loss history and building characteristics to determine the optimal premium. The proposed methodology is implemented to a well-acknowledged compulsory earthquake scheme in the World, *Turkish Insurance Catastrophe Insurance Pool (TCIP*, Turkish synonym *DASK*), as TCIP sets basic premium rates by only taking into account two parameters: Seismic hazard level and building type. Hence, TCIP premiums ignore the specific characteristics such as the number of storey, damage status, risk floor number and the construction date underestimating the real premium rates. Another missing information is the state of the buildings before and after the shake. A Markovian approach is employed to determine the transition probabilities between damage states based on the available data in the literature. This study is expected to contribute the adjustment of TCIP rates to assure its financial stability and propose an algorithm for determining private earthquake insurance rates under insufficient loss history.

Introduced and implemented in 2001, TCIP serves as a buffer for Turkish Government to compensate earthquake losses and the funds it generates attracts international reinsurance companies. Compulsory Earthquake Insurance (CEI) which is a stand-alone product and issued by TCIP and insurance companies, is obligatory for residential buildings fulfilling certain conditions. TCIP was originally designed for multi-peril hazard insurer, offer for the time being only earthquake insurance by a Decree Law. Earthquake coverage is limited by a maximum amount which is held the same for every dwelling. Predetermined premiums are adjusted every

year based on the market value of the residential buildings in respect to only three-construction types and the seismic zone that they are located on. Premium rates depend highly on the earthquake loss estimation. One of the important factors of the pool with both its pros and its cons is given by low premium rates that do not reflect the accurate coverage for an earthquake risk. Based on data from Turkey, this study suggests the risk which may lead to such low rates, the load to be added on the variables which have an impact on the rates that are not in practice or not taken into account yet.

In literature, many studies on seismic vulnerability assessment methods depending on empirical and theoretical approaches incorporate also the randomness on the ground motion variability [7, 8, 10, 12, 14, 15]. There exist vast amount of studies on the seismic loss estimation for Turkey as 91.4% of its land is under seismic threat [3, 4, 22, 11]. The study on conditional probabilities of damage states based on different levels of earthquake intensity introduced by [19] is one of the major literature in earthquake risk premium assessment. His method has also been utilized to determine rates for TCIP by [21], and Deniz and Yucemen [6]. Besides its thorough analyses on the premium levels, these studies indicate that the best estimate of TCIP total premium should be 2.7 times more than the existing rates [21]. The findings in these studies emphasize that the TCIP premium rates in act should be examined in order to preserve its financial stability even though the CEI aims to offer the minimum coverage. Additionally, the Government intervention on regulating the tariffs will be released in near future, which will bring higher risk to insurance companies to set their own premium ratings as an excess of loss scheme as combined to TCIP rates.

## 2. PREMIUM VALUATION OF EARTHQUAKE INSURANCE

The valuation of earthquake insurance premium rates is based on the conditional probability of damage given the earthquake hazard level. The frequency of the earthquake which is the same for all structures may result in severity changing with respect to the structural properties such as system type, age and configuration. The components of the rates are as follows: (i) *Estimation of the seismic hazard*; this is a probabilistic seismic hazard analysis which determines the survival probability of the structure under certain seismic load. The randomness in the occurrence of earthquake, in magnitude, time and location, follows certain probability distributions which allow to estimate the conditional probability of intensity exceeding a certain level causing damage. Under distributional assumptions, the earthquake magnitude obeys an exponential distribution; the occurrence of earthquake in space is assumed to have a uniform distribution over the seismic location, mostly defined in the form of a fault; and the Poisson distribution is considered to present the behavior of number of events over time domain [2, 21]. (ii) *Estimation of potential damage*; the seismic vulnerability depends on the random capacity of the structure, which is modelled by a probabilistic approach. Damage probability

depends on the state of the structure with respect to the level of seismic threat. For this purpose, a *Damage Probability Matrix (DPM)* is constructed to illustrate the impact of different seismic intensity levels ( $I$ ), on the physical condition, called *damage state (DS)*, of the structure [19]. Each component in DPM refers to,  $P_k(DS, I)$  which is the empirical probability of the  $k$ th type structure being prone to a seismic intensity level,  $I$ , ending up with a damage state,  $DS$ . The damage states are categorized as *no damage (N)*; *light damage (L)*; *moderate damage (M)* and *heavy damage/collapse (H/C)*. The structure types being considered are classified as steel-concrete, masonry and others. The main measure in determining the probabilities is damage ratio ( $DR$ ) which is the proportion of repairing earthquake damage cost to the replacement cost of the structure.  $DR$  may show a wide range of realizations, therefore, for simplicity, a single  $DR$ , called *central DR (CDR)*, is assigned to each  $DS$ .  $CDR$  for each state of damage is set to 0%, 5%, 30%, and 85% for N, L, M and H/C states, respectively, according to the DS classification by the General Directorate of Disaster Affairs of the Ministry of Public Works and Settlement in Turkey [1]. The *mean damage ratio (MDR)* for each intensity level,  $I$ , is defined as follows [2]:

$$MDR_k(I) = \sum_{DS} P_k(DS, I) \cdot CDR_{DS}, \quad (1)$$

where  $DS$  represents the damage state taking values on the set  $\{N, L, M, H, C\}$ . In [21], an earthquake damage measure for  $k$ th type of buildings, the expected annual damage ratio ( $EADR_k$ ), is defined by:

$$EADR_k = \sum_I MDR_k(I) \cdot SH_I, \quad (2)$$

where  $SH_I$  is the annual probability of an earthquake with intensity  $I$ , occurring at the site. Then, the pure risk premium,  $\pi_k$ , for a  $k$ th type structure having insured value of  $G$  can be calculated as

$$\pi_k = EADR_k \cdot G.$$

According to the premium principles, a load factor,  $\theta$ , has to be charged to the pure premium to cover additional and unexpected costs which finalizes the gross premium,  $\Phi_k$ , valuation as described below:

$$\Phi_k = \pi_k(1 + \theta);$$

here, the index  $k$  denotes the construction type described above.

### 3. BAYESIAN REGRESSION MODEL

Bayesian regression whose prior information takes its base from the linear regression, incorporates both the parameters and the data as random variables. The main advantage of this method is to capture the randomness in the estimators of

linear regression model by using conditional probability distributions. The multiple linear regression model with an informative prior is written as

$$y = X\beta + \epsilon, \quad (3)$$

where  $y$  denotes an  $n \times 1$  vector of dependent variables,  $X$  represents an  $n \times k$  matrix of explanatory variables, and  $\epsilon$  is an  $n \times 1$  random error vector having normal distribution with mean  $\mu$  and variance  $\sigma^2 I_n$ . Linear regression models require the parameters  $(\beta, \sigma)$  to be estimated for which we assign a prior density of the form  $h(\beta, \sigma) = h_1(\beta)h_2(\sigma)$  [9]. Hence, we make the assumption that the prior for  $\beta$  is independent from that of  $\sigma$ . Moreover, with this prior density, we specify the mean and variance for these parameters as follows

$$\beta \sim N(r, T) \text{ and } h_1(\beta) \propto \exp\left[-\frac{1}{2}(\beta - r)'T^{-1}(\beta - r)\right].$$

Here,  $T$  is the  $m \times m$  prior variance covariance matrix consisting prior values of covariance. For the case when  $m < k$ , the above equation is improper. For this reason an alternative form by factorizing  $T^{-1}$  into  $Q'Q^{-1}$  and  $q = Qr$  leads to

$$Q\beta \sim N(q, I_m) \text{ and } h_1(\beta) \propto \exp\left\{-\frac{1}{2}(Q\beta - q)'(Q\beta - q)\right\}.$$

For simplicity, we suppose the flat prior  $h_2(\sigma) \propto \frac{1}{\alpha}$  for  $\sigma$ . Following the Bayesian approach, the likelihood function is written as

$$L(\beta, \sigma) \propto \frac{1}{\sigma^n} \exp[-(y - X\beta)'] \quad (4)$$

yields the posterior density for  $(\beta, \sigma)$  as

$$\begin{aligned} p(\beta, \sigma) &\propto \left(\frac{1}{\sigma^{n+1}}\right) \exp[\beta - \hat{\beta}(\sigma)]' [V(\sigma)]^{-1} [\beta - \hat{\beta}(\sigma)] \\ \hat{\beta}(\sigma) &= (X'X + \sigma^2 Q'Q)^{-1} (X'y + \sigma^2 Q'q) \\ V(\sigma) &= \sigma^2 (X'X + \sigma^2 Q'Q)^{-1}. \end{aligned} \quad (5)$$

As the mean and variance of the posterior is conditional on  $\sigma$ , the Bayesian regression problem does not have an analytical solution. Therefore, for tractability, we follow the approach of Theil and Goldberger [24] and replace  $\sigma^2$  by the estimated value  $\hat{\sigma}^2 = (y - X\hat{\beta})'(y - X\hat{\beta})/(n - k)$ , which depends on the least-squares estimate  $\hat{\beta}$ . The produced point *Theil* estimator  $\hat{\beta}_{TG}$  and its variance-covariance are given as

$$\begin{aligned} \hat{\beta}_{TG} &= (X'X + \hat{\sigma}^2 Q'Q)^{-1} (X'y + \hat{\sigma}^2 Q'q), \\ \text{var}(\hat{\beta}_{TG}) &= \hat{\sigma}^2 (X'X + \hat{\sigma}^2 Q'Q)^{-1}. \end{aligned} \quad (6)$$

In order to provide a solution to the Bayesian multiple integration under the conditional densities, Gibbs sampler is employed. Two-step Gibbs sampler approach to the Bayesian regression described above is implemented to obtain the mean and the variance of posterior distribution for  $\beta$  conditional on  $\sigma$ , as given in Eqn. (5).

The posterior marginal density of  $\sigma$  conditional on  $\beta$  with flat prior is a scaled inverse  $\chi^2$  which is given as

$$p(\sigma|\beta) \propto \left(\frac{1}{\sigma(n+1)}\right) \exp[-(y - X\beta)'(y - X\beta)], \quad (7)$$

with

$$[(y - X\beta)^2]|\beta \sim \chi^2(n). \quad (8)$$

Using these two conditional posterior probabilities, we estimate the parameters  $(\beta, \sigma)$  through Gibbs sampler computations which finally, on average, converges to the joint posterior density.

#### 4. TCIP

Earthquake insurance in Turkey which has been provided as a joint peril to the fire and engineering policies had a low penetration before 2000. Continuing disasters with severe economic impacts led Turkish Government to establish an insurance scheme. Accelerated by the Marmara disasters in August and November 1999, the Turkish Catastrophe Insurance Pool (TCIP) was created and Compulsory Earthquake Insurance (CEI) was made obligatory for all residential buildings that fall within municipality boundaries. The legal framework of the new scheme was established by a decree law at which the government's obligation by the Disaster Law to extend credit and construct buildings for the victims of earthquake disaster was avoided [20]. The insurance coverage at affordable premiums is aimed to decrease the financial load of earthquakes on the government budget, mostly resulting from the construction of post disaster housing, to share the risk among residents, to ensure standard building codes, and to build up sustainable reserves to financial future earthquake losses. Meanwhile, international reinsurance markets also take a considerable share in reducing the risk.

The organizational form of TCIP makes it a legal public entity managed through the TCIP Management Board and operated by a private insurance company. The Board consists of representatives of the Prime Ministry, the Treasury, Ministry of Public Works and Settlement, the Capital Market Board, the Association of Insurers, the Operational Manager, and an earthquake scientist. Operational management is being contracted out to an insurance company for every five years in order to reduce the administrative costs whose payment is relative to the overall volume of premiums written. Non-life insurance companies act as the distributors and are the participants of the systems whose commissions depend also on the volume of the premiums they collect. Being exempt from corporate tax, TCIP funds are managed by the operational manager and asset management companies [20].

To attain the adequate level of coverage, TCIP sets affordable premiums which require an upper limit on the coverage (approximately USD 80,000 [5]). Excess of this upper limit can be covered by purchasing earthquake insurance on a voluntary basis. Unit reconstruction cost times the gross square meter of dwelling determine

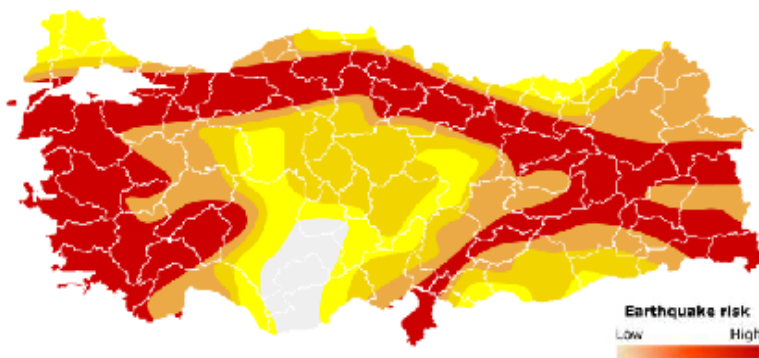


FIGURE 1. Earthquake zone map for Turkey ([5])

the sum insured with a 2% deductible. The claim payment is determined based on the market reconstruction prices at the date of event occurrence for each type of building which is limited to the sum insured. Three categories of construction type (steel-concrete, masonry, other) and the five seismicity levels are used to determine the insurance rates. Figure 1 illustrates the map of seismic zones in Turkey [5] and the current tariff rates set by TCIP are given in Table 1. It should be noted that factors such as age of the building, the number of floors, etc., are not included in the valuation of the premiums.

TABLE 1. TCIP insurance rates [5]

Type of Construction	Risk Regions				
	I	II	III	IV	V
	Insurance Rates (%)				
Steel, concrete	2.20	1.55	0.83	0.55	0.44
Masonry	3.85	2.75	1.43	0.60	0.50
Other	5.50	3.53	1.76	0.78	0.58

The premium contributions and investment income which constitute the funding of TCIP will not be sufficient to cover a major disaster. In such a case, the major part of the risk of TCIP is transferred to the international reinsurance markets. For a 250 years return period, TCIP has a claim capacity over USD 3 billion of which 2/3 is under reinsurance coverage. Since its establishment, many small-size, but not destructive earthquakes have been experienced in Turkey until a severe earthquake hit the province Van in 2011, causing TCIP claim payment of USD 4,4934,744. The history of earthquakes in Turkey last 13 years indicates that small and medium-size earthquakes occur with high frequency, leading a total 430 incidences with a total payment of USD 54,012,641 with an increasing rate [5]. It

should also be taken into account that this increase is proportional to the number of policies every year. As of its introduction to the public, the total number of TCIP policies has increased tremendously from 159 to 6,029,000 between the years 2000 and 2013, producing a total premium of USD 232,478 in 2013 [5]. Even though the percentage of building inventory covered by TCIP is low (around 27%), the increasing rate in the number of policies over years is encouraging. It has been noted that the insurance take-up rates resulted in an increase of 5% after Van earthquake. The geographic distribution of policies indicates that the penetration rate varies with respect to the earthquake experience and the economic development of the region in Turkey. The low penetration stems from a relatively low insurance culture, the accustomed compensation of disaster damages over years creating an expectation from government, economics welfare of the individuals and weak enforcement. However, public information and education advertisements on TCIP, such as broadcasts, printed documents, contests, collaboration with experts and academics and earthquake simulation trailer travelling nation-wide, increase the awareness on the importance of insurance in disaster management.

## 5. OPTIMAL LOAD FACTORS FOR TCIP

TCIP database system collects loss history, premium and many characteristics of each policy and pertains a huge information pool. The scope of this case study is restricted to one province, the city of Eskişehir which is located in Central Anatolia region with seismic zone categorization of two (*II*). Because of its fusible soil structure with a high groundwater level and an active fault passing beneath the center, the city has experienced many earthquakes with intensities greater than five (*V*). In the light of these facts, carrying out a probabilistic premium estimation using Eskişehir earthquake insurance data, is of great importance.

The data set is comprised of building features and premium information for each policyholder in Eskişehir with additional building features as: insurance amount, risk floor number, construction date, number of storey, damage status, construction type and storey area for a sample size of  $n = 12768$ . A majority of these features, which are crucial factors in the loss estimation, are ignored in the TCIP premium calculation methodology. Therefore, TCIP underestimates the expected value of damage and loss which then would result in an inevitable financial burden in case of a spatially large catastrophe. For the theoretical estimation of the expected loss resulted after an earthquake with intensity  $I$ , some conditional probabilities regarding damage and earthquake occurrences are required. In the next subsection, we describe the steps of determination of these values.

**5.1. Transition Probabilities of Damage States.** The levels of damage states described in Section 2 are reduced to  $N$ ,  $L$  and  $M$  as the data history does not include  $H/C$  cases. The empirical damage state probabilities obtained in [21], represent the probabilities of occurrence of a particular  $DS$  when the structure of  $k$ th type is subjected to an earthquake of intensity  $I$ . However, the vulnerability



of a building towards earthquake depends on its pre-earthquake damage state as well. The information on pre- and post-damage state of the buildings converted into a transition from one state to another has not been studied for the building inventory in Turkey. Therefore, using the damage state probabilities as post-event probabilities, we introduce Markov Chain approach to estimate damage state transition probabilities for each intensity  $I$ . The damage state transition probability estimates can be calculated as follows:

$$P_k(DS_j, I) = \sum_{i \leq j} P_k^0(DS_i) P_k(DS_i - DS_j, I), \quad (9)$$

where  $P_k(DS_i - DS_j, I)$  denotes the probability of transition from damage state  $i$  to damage state  $j$  when an earthquake of intensity  $I$  occurs, and  $P_k^0(DS_i)$  is the pre-earthquake ratio of the buildings with damage state  $i$  in our data set.

Eskişehir data are composed of non-damaged building policies. Therefore, we set the empirical pre-earthquake probability of being in state  $N$  to be 1 and other states as 0. Carrying on the computations we obtain the transition probabilities  $P_{N-N}$  and  $P_{N-L}$  for each earthquake intensity.

To illustrate, for steel-concrete buildings given intensity  $VII$ , the transition probability matrix of damage states,  $M_k(I)$  is derived in the following form:

$$M_{steel}(VII) = \begin{bmatrix} 0.45 & 0.39 & 0.125 & 0.035 & 0 \\ 0 & P_k(L-L, VII) & P_k(L-M, VII) & P_k(L-H, VII) & P_k(L-C, VII) \\ 0 & 0 & P_k(M-M, VII) & P_k(M-H, VII) & P_k(M-C, VII) \\ 0 & 0 & 0 & P_k(H-H, VII) & P_k(H-C, VII) \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

Each row and each column in the matrix correspond to the states  $N, L, M, H$  and  $C$  in consecutive order. This table can be easily updated for a different data set. In case of a rich data set which consists of damage states other than  $N$ , the transition probabilities can also be computed. The annual earthquake occurrence probabilities corresponding to different intensity levels which are derived via interpolation presented in Table 2 [6]. These are taken as an input in calculating the expected losses in determining the net premium. As TCIP covers losses resulted from earthquakes with intensities higher than  $V$ , and the probability of an earthquake with  $I \geq VIII$  is insignificant in Eskişehir, we consider intensities between  $V$  and  $VIII$ .

TABLE 2. Annual occurrence probabilities for the intensity levels V-VIII [6].

Zone	City	Intensity			
		V	VI	VII	VIII
2	Eskişehir	1.46E-01	5.21E-02	1.63E-02	4.25E-03

Based on both the central damage ratios ( $CDR$ ) given in [21], and the transition probabilities introduced in this paper, the premiums are modified. The  $CDR$  ratios multiplied by the insurance coverage amounts written on a TCIP policy are used

to calculate the cost of repairing. The expected value of the loss,  $L_n$ , for the  $n$ th policy given the building type then becomes

$$\mathbb{E}(L_n) = \sum_{V \leq I \leq VIII} P(I = l) \mathbb{E}(L_n | I = l), \quad (10)$$

where

$$\mathbb{E}(L_n | I = l) = \left( \sum_{i,j \in \{N,L,M,H,C\}} P(DS_i - DS_j, I) CDR_{DS_j} \right) G_n.$$

Here,  $G_n$  represents the insurance amount for each policyholder. Using the annual probabilities in Table 2 and the transition probabilities we derived, we calculate the expected loss for each earthquake intensity. From the theoretical point of view, the premium is calculated based on the assumption that it should remain below the expected loss with a certain buffer by adding a load factor  $\theta$ . The load or safety factor  $\theta$  is taken to be 0.67 as recommended by experts from Turkish insurance sector. Then, the risk premium for the  $n$ th policy,  $\pi_n$ , becomes

$$\Phi_n = \pi_n(1.67). \quad (11)$$

It should be noted that  $\Phi_n$  represents the embedded impact of the damage state transition probability, central damage ratio and insurance amount which shows variation based on the characteristics of the building. The portfolio of the buildings in TCIP for this region will bring an estimated total loss of

$$\Phi = \sum_n \Phi_n. \quad (12)$$

The proposed premium estimation method suggests employing a Bayesian linear regression model where the dependent variable  $y$  is the theoretical premium derived from Eqn. (11),  $X$  is an  $n \times k$  matrix of the explanatory variables and the  $1 \times n$  vector  $\beta$  consists of the estimates of the following  $k = 10$  independent parametric variables: *insurance amount*, risk floor number, construction date, number of storey, damage status, construction type and storey area. Following the Bayesian approach, for the parameters  $\beta$  and  $\sigma$  to be estimated in Eqn. (3), we assign normal and inverse chi-square prior densities, respectively, with the prior mean and variance values obtained from the linear regression. The estimation procedure is carried out by Gibbs-sampler and the estimate results are shown in Table 3. The categorical variables such as age and storey number are included into the model as dummy variables. Three categories are defined for each variables at which two dummy relate two categories in the age of the building, and two for the storey numbers. In each cases zero corresponds to the categories "buildings constructed before 1975", and "storey between 0-4", respectively.

The diagnostic tests of the Bayesian regression verify the significance of the parameters and the validity of the model. The parameter estimates shown in Table 3 are consistent with the contribution they make to the premium with respect to their

TABLE 3. Bayesian regression estimates to adjust TCIP premiums

Independent Variables	Coefficient	Std. Dev.	t-statistic	t-probability
Intercept	39.0268	1.0908	62.3291	0.0000
Insurance amount	0.0021	0.0026	299.1839	0.0000
Risk floor number	-0.6456	0.2594	-10.1141	0.0000
Const. date (> 2000)	3.2143	0.851469	6.9969	0.0000
Const. date (1975-2000)	2.3147	0.855570	4.9770	0.0001
Number of storey (> 8)	-3.0926	0.666333	-8.3740	0.0000
Number of storey (5-7)	-0.27	0.5347	-1.0827	0.2789
Storey area	0.0309	0.0501	12.3584	0.0000
Const. type (Steel, Concrete)	-40.0649	1.1090	-63.6899	0.0000
Const. type (Masonry)	11.6730	1.1401	16.9238	0.0000
$R^2 = 0.9415$	$\sigma = 12.96$	$n = 12768, k = 10$		

association to it. Based on the estimates we can conclude that an increase in the risk floor number reduces the premium, the age of the building has a positive significant load on the premium, and the number of storey more than 8 has more impact than smaller number of storeys. The construction type of the steel and concrete buildings substantially decreases the premium amount due to the endurance level of the building. On the other hand, the premium of a masonry building which corresponds to an unstable building type is increased by 11.67 as expected. For comparison, we derive the optimal insurance amounts given by Eqn. (11) based on the coefficients estimated by Bayesian regression analysis. Then, we estimate the tariff rates for Risk Region II taking Eskişehir as the representative. The estimates are presented in Table 4.

TABLE 4. Proposed Tariff rates

Construction Type	Tariff Rates for Risk Region II ( <sup>0</sup> / <sub>00</sub> )		Load
	Bayesian	TCIP	
Steel, concrete	2.62	1.55	69%
Masonry	3.68	2.75	34%
Other	5.33	3.53	51%

It can be seen from Table 4 that the tariff rates set by TCIP underestimate the risk financially. As suggested by earlier studies, higher premium rates need to be set for TCIP. The findings in the proposed study justify the literature, yet, concluding affordable rates and incorporating more uncertainty.

We can argue that the Bayesian regression method applied in this study is more suitable for estimating earthquake premiums in Turkey compared with the methods that only use the knowledge of earthquake damage probability and ratios. Also, the Markov chain approach through damage state transition probabilities has a positive effect on the reliability of the model as the information coming from the damage process of a building is not neglected. The necessary update in tariff rates is implied as a result of these factors.

## 6. CONCLUSIONS

Risk management belongs to the challenging research subjects of modern Management Sciences. This paper is a novel contribution in this respect by that a modified self-subsidizing catastrophe management system is proposed for TCIP. Risk management of the funds in the pool is vital since Turkey's high earthquake risk may result in catastrophic losses. Decision makers in pool management and in reinsurance and financial markets solely depend on how much economic losses are expected in the future. Revealing a low premium rate for the purposes of affordability, TCIP has to encounter the risk that the fund is prone to and the determination of appropriate tools is gaining a fast importance [17]. This paper introduces the implementation of Bayesian regression on the quantification of optimal premium values in the frame of a compulsory earthquake scheme in Turkey. Compulsory Earthquake Insurance coverage is provided by TCIP a growing interest in Turkey and international markets. TCIP enforces earthquake resistant construction quality, generates funding after an earthquake, relieves the burden on economy and gives relief to the homeowners. Low premium rates to attain its affordability may endanger the capacity of the accumulated funds after a devastating earthquake, even though some part of the risk is already distributed to the reinsurance market. The contribution of this paper is not only limited to the quantification the influence of the unconsidered variables on the premium rates. Damage state probability estimation of pre- and post-earthquakes is empirically calculated based on the historical observations by Markov chain approach. The analysis applied shows that premium rates incorporating the influence of risk factors suggest much higher rates, while still remaining in the range of financial affordability. The methodology proposed here is going to be extended to the other provinces of Turkey as an ongoing study.

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