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RISK MANAGEMENT STRATEGIES FOR MANAGING NATURAL DISASTER RISKS: A CASE STUDY IN SHIRAZ CITY, IRAN

N. Pakdel-Lahiji[1], S. Hochrainer-Stigler[2], M. Ghafory-Ashtiany[3] and M. Sadeghi[1]

ABSTRACT

Almost all parts of Iran are seismic hazard prone areas and due to the low quality of constructions as well as the increase of exposure in urban areas, recent earthquake events caused unacceptable huge losses, both in human and economic terms. To assess the resilience of various risk bearers, including the government as well as private sector entities, the resources to cope with potential future events as well as possible interdependencies during the occurrence have to be analyzed in detail. Furthermore, to pro-actively act against possible future extremes with risk hedging instruments such as insurance, the underlying risk has to be determined in a quantitative manner. This paper suggest how to combine both, the coping dimension as well as the risk dimension, to determine possible risk management strategies which may be feasible in the Iranian context. The focus is specifically on risk instruments, such as insurance, for the Shiraz region in Iran, where newly produced probabilistic loss estimates are available which are subsequently used to analyze possible insurance schemes and for determining corresponding premium payments as well as affordability. The paper discusses how such risk instruments can be embedded within an integrated framework and which additional options, such as risk reduction or risk pooling, would be beneficial to lower premiums to affordable levels.

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ABSTRACT

Almost all parts of Iran are seismic hazard prone areas and due to the low quality of constructions as well as the increase of exposure in urban areas, recent earthquake events caused unacceptable huge losses, both in human and economic terms. To assess the resilience of various risk bearers, including the government as well as private sector entities, the resources to cope with potential future events as well as possible interdependencies during the occurrence have to be analyzed in detail. Furthermore, to pro-actively act against possible future extremes with risk hedging instruments such as insurance, the underlying risk has to be determined in a quantitative manner. This paper suggest how to combine both, the coping dimension as well as the risk dimension, to determine possible risk management strategies which may be feasible in the Iranian context. The focus is specifically on risk instruments, such as insurance, for the Shiraz region in Iran, where newly produced probabilistic loss estimates are available which are subsequently used to analyze possible insurance schemes and for determining corresponding premium payments and affordability. The paper discusses how such risk instruments can be embedded within an integrated framework and which additional options, such as risk reduction or risk pooling, would be beneficial to lower premiums to affordable levels.

Introduction

Iran is one of the most earthquake-prone countries in the world. In the 20th century alone, 22 major earthquakes have happened and claimed over 150,000 lives. Part of the reason for the exceptional high human and economic losses in the past, include the failure of most physical structures to withstand the impact [1]. As indicated, also the economic losses for different risk bearers, e.g. the government or households, were huge and difficult (or even impossible) to be financed without any assistance. Fig. 1 shows total direct loss estimates for major earthquakes which have happened in the recent past and recovery investments to finance them. What can be noticed is the discrepancy between financing needs and available financing resources. In all cases there is a gap between earthquake losses and recovery investments but it’s worthwhile to note that the absolute gap is completely different for each event. This has, as it is often the case, also to do with political aspects and media attention [2].

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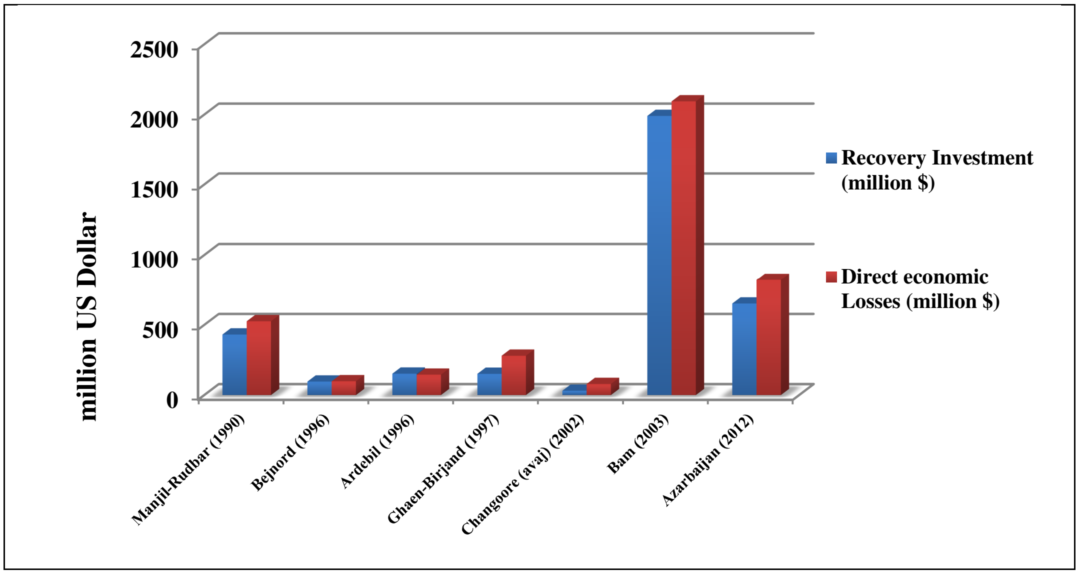


Figure 1. Past major earthquake losses in IRAN [3].

The high level of seismicity in combination with a high physical vulnerability of structures leads to a high earthquake risk level for Iran and therefore is unacceptable and has to be managed in some way. Basically, there are two main approaches to manage the risk: risk spreading and risk mitigation methods. The main focus here is on risk spreading instruments, such as insurance, and will be applied within a specific case study, namely for Shiraz city. However, before considering possible risk management schemes one has to assess the current financial vulnerability of the government and households against potential catastrophe losses (we focus here mostly on households). Such kind of analysis is needed to detect the risk level at which the different risk bearers are assumed to behave risk averse, and therefore would be interested in risk spreading instruments such as insurance. In other words, it is assumed that only the risk which cannot be absorbed without any major difficulties via current resources should be hedged, for example via insurance.

In order to quantify the financial vulnerability of households against earthquake events, first, the situation of the households after past major earthquake events is investigated in detail and the total resource stock available to finance the losses is assessed. In a next step, the financial vulnerability of the households against catastrophe events is assessed by comparing the maximum financing resources with the potential losses earthquake events could cause. This enables us to determine the risk level for a given risk bearer, i.e. we assess the probability that an earthquake event would cause losses which exceed the ability of the risk bearer to finance them, or in other words that a financing gap occurs [4]. In a next step this information is used to suggest possible insurance schemes and corresponding premiums to hedge the remaining risk.

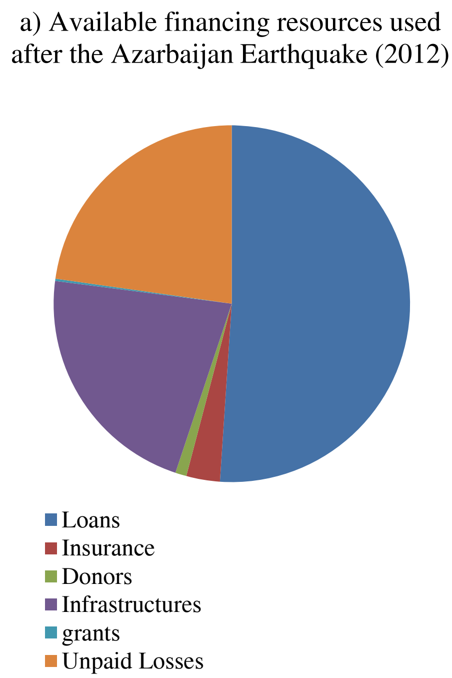
Assessing Current Financial Vulnerability of Households

In order to assess the current financial vulnerability of households against extremes, the loss financing instruments used in past major earthquake events have been investigated in detail. It was found that households, especially the low income ones, very much rely on government assistance and insurance. However, the later one only plays a very small role, about 2-3 percent of total losses. Government assistance came in different forms, for example, giving subsidized long term low-interest loans, providing technical assistance (including design, consultation, and implementation), monitoring, preparing plans and designs for earthquake resistance structures, repairing infrastructure (road construction, debris removal, piping), grant construction material and other resources, as well as supporting the poor. Here, the focus will be on financial resources needed to recover from losses and current financial vulnerability of households is determined given the current available ex-post or ex-ante measures. Furthermore, it is assumed that:

- a one year time horizon, i.e. the disaster is assumed to happen at the beginning of the year and the financial situation of the households at the end of the year is calculated thereafter
- a range of k different ex-post financial instruments the government/households can or may use is available
- the ex-post measures come into play immediately after the disaster happens and are available without any time delay.

It should be noted that we used the inflation rate based on the statistical data of Iran [5] for transforming current values into constant ones.

One way in providing an estimate of the financial vulnerability of the households which is useful for insurance purposes is by calculating the critical year event or critical return period. It is defined as the smallest (earthquake) year event which causes the financing gap for the first time. In other words, the critical year event causes the depletion of all resources available which can be used for after an event but would not cause a financing gap (and hence all losses still can be financed) [4]. Consequently, for quantifying the financial vulnerability, the maximum amount of instruments/resources which can be used after the disaster must be calculated first. In order to find all possible financial resources available which can be used after earthquakes, passed loss payments for recent earthquakes have been studied and transformed to constant dollars using the inflation rate already mentioned above. Generally speaking, based on this previous earthquake loss financing analysis in Iran, the possible instruments include loans, grants, donor assistance (in terms of relief goods or cash), insurance and indirect payments of the government to the earthquake hit regions. Figure 1 shows two examples of loss payments by different instruments after the Bam 2003 earthquake and after the 2012 earthquake in Azerbaijan, which caused 2094 and 822 million $ losses, respectively. It is important to note that the magnitude of the Bam and Azerbaijan earthquake were only around 6.5 and 6.4 in magnitude but caused very high losses. An indication that even moderate earthquakes can cause exceptional losses due to the high structural vulnerability of the buildings in Iran.



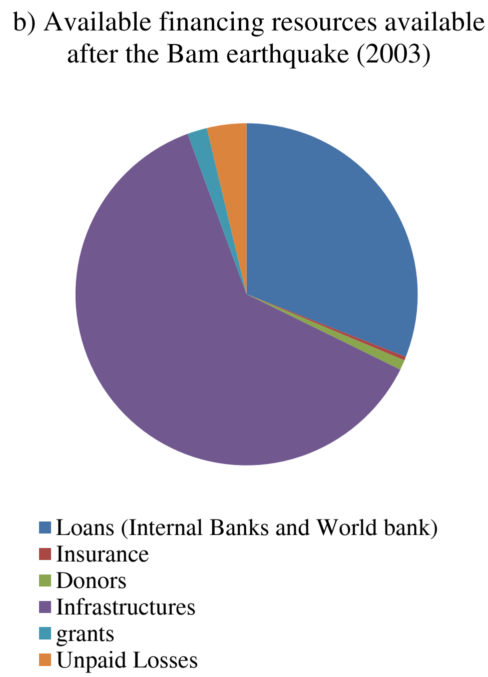


Figure 2. (a) Loss financing resources used in Azarbaijan earthquake (2012) and (b) Bam earthquake (2003).

Based on Fig. 2 the largest part of the losses to households are paid by low interest and long term loans; it should be kept in mind that such loans are just providing enough money to construct a small house, approximately around 60-70 square meters, and for compensating only part of the actual losses. As both figures suggest, the high amount of unpaid losses as well as the risk of getting a smaller house after an event (as not enough resources available to fully rebuilt to pre-event structures) indicate a need to further investigate possible risk management strategies, including risk financing instruments such as insurance, an insurance pool, catastrophe bonds or some mitigation measures to decrease the underlying risk. Table 1 summarizes the estimated available resources based on detailed case study analysis of the 7 most recent earthquake events (under the assumptions given above).

Table 1. Maximum amount of financing resources of households for disaster losses in Iran.

Replacement Loan (urban buildings) ($)	**Repair Loan ($)**	**Grants ($)**	**Insurance payment (% of total loss)**	**Donor assistance (% of total loss)**	**Government Indirect assistances (% of the loan)**
10086	2824	1210	1.54	1	30

In more detail, there are three types of loans available for people after earthquake events, a loan for constructing urban buildings, another one for constructing rural buildings and the other one for repairing the buildings. If the losses are less than a specified percentage of total value of the structure, the household can get a repair loan and if losses are larger, they can get access to a replacement loan from the government. The specified percentage is assumed to be around the 30% value (based on past analysis). The grant is an assistance of the government to all households and focus on living costs after the earthquakes. As indicated the insurance penetration in Iran is very low but past earthquake events have shown that the claims have been rapidly paid after the events. About 10% of the buildings have earthquake insurance coverage [6]. Donor assistance which can be in monetary terms or via relief goods were variable for each earthquake in the past, but is small and around 1% of total losses.

Additional to the assessment of the possible resources available to finance losses it is necessary to estimate the probability of a given earthquake event and corresponding losses such an event would cause. We rely on newly produced earthquake risk estimates for Shiraz city for a comprehensive set of structures [7]. Let's call the loss distribution for a given building *F* and the maximum amount for a given event and given resource i (=1,...,k) as b_i. Using all the financial resources available the critical return period can be calculated as in Eq. 1:

$$\text{Critical return period} = \frac{1}{1 - F(\sum_{i=1}^{k} b_i)} \tag{1}$$

The buildings analyzed here (see [7]) are classified in regards to three building codes related to the year of constructions (Pre-code, moderate-code and high-code) which is based on several editions of the Iranian seismic codes [8], i.e. buildings constructed before 1991, from 1991 to 2005 and after 2005 are related to Pre, moderate and high-code, respectively. Furthermore, we distinguish between steel, concrete and masonry type of structures as well as differentiated according to number of stories. The critical return period for all types of buildings have been calculated using the approach explained above and corresponding results are shown in Table 2.

Table 2. Critical return period for different building classes in Shiraz city.

Types of buildings	**Number of stories**	**Critical year Event**		
		Pre-Code	**Moderate-Code**	**High-Code**
Steel	1-3	7	71	449
	4-7	9	69	200
	> 8	8	39	87
Concrete	1-3	7	59	443
	4-7	8	69	315
	> 8	-	-	128
Masonry	1-2	12	123	1248
	3	7	119	698

Note, the smaller the critical year event, the higher the risk (and vice versa). The smallest number and therefore highest risk (in terms of financial vulnerability) shown in Table 2 is for pre-code, 1-3 story, steel structures; the critical year event is estimated to be a 7 year event which means that, on average, every 7 years such an household will experience a financing gap, or in other words a situation where losses are larger than their maximum amount of resources available to finance them. This result is (while important) rather unsurprising as this kind of buildings are occupied mostly by rather poor households with small resources as well as high structural vulnerability (hence, the small numbers for the whole pre-code building column). The opposite is the case for the high-code column in Table 2. Another important issue to be considered is the fact that the critical return period is increasing very sharply from pre-code to moderate-code buildings and also from moderate-code to high-code buildings. The results are very important as it will give indications which households may want to decrease risk via risk spreading instruments such as insurance. Possible insurance schemes for earthquake risk for Iran based on these results are presented next.

Catastrophe Insurance in Iran

The results in the last section showed that especially buildings constructed before 1991 and between 1991 and 2005 are at high risk. In Iran insurance could play an important role to repay the losses immediately after earthquakes and therefore help to decrease possible negative long term consequences for risk bearers as well as stabilizing budget planning processes over longer time horizons. However, currently there is no separate insurance coverage for earthquake risk available in Iran; it is only included as an option for fire insurance. Based on past experiences of other countries on earthquake insurance, the inclusion of earthquake as a standard peril within a fire policy was generally restricted to home insurance and to areas where earthquake risk was considered negligible [9].

Regarding what type of insurance schemes would be most promising ones, we already noted that not all of the risk bearer is exposed to, needs to be transferred to the insurance sector (only the part of the risk he is not able to cover by himself). The critical year event concept gives some indications which kind of risk needs to be transferred and is coupled now with some specific insurance schemes, specifically Excess-of-Loss reinsurance types.

Large unbalanced risks like catastrophe risks are usually insured as non-proportional treaties where the reinsurer contractually agrees to pay for a certain layer of losses, i.e. the ceding insurer (or risk bearer) bears the losses up to a certain point (called the attachment point or deductible), and afterwards the (re-)insurer steps in, but usually only up to a maximum limit (called the exit or exhaustion point) (see [10], [11]). One type of non-proportional reinsurance is Excess-of-Loss (XL) reinsurance. It is the dominant reinsurance cover for natural disasters [10 and 11].

The use of risk based premiums does not just provide an insurance company with a way of enhancing its competitiveness through being able to attract good risks by providing more attractive terms and deterring bad risks by high premiums, deductibles or other means. It also makes earthquake insurance not only important for the recovery process of disaster management, but also can create incentives for disaster mitigation [12].Risk based premiums are therefore very important to raise risk awareness of the households and paying more attention to earthquake resistant constructions and using mitigation measures to decrease the inherent risk, which consequently would also lower the premiums.

However, a probabilistic risk assessment of the region is needed to calculate risk-based premiums. Exceedance probability curves (EP curve) based on probabilistic risk assessment of the region for each building class (again based on [7]) are used for calculating the corresponding risk-based premiums for all building types in Table 1. One example of EP curves used here for Shiraz city is shown in Fig 3.

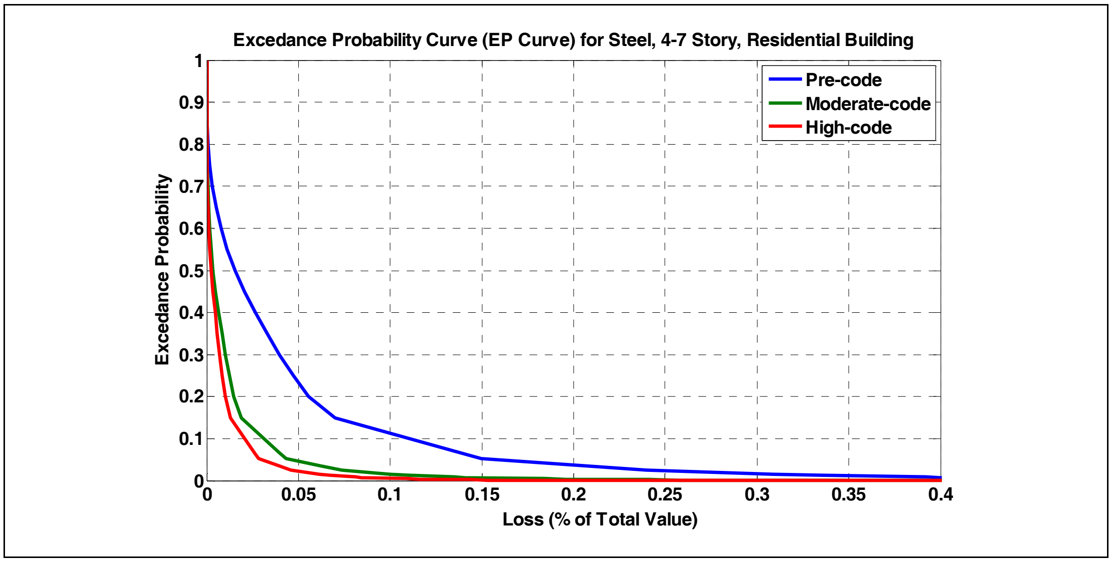


Figure 3. Exceedance probability curve for Steel structure, 4-7 story buildings [7].

In combination of the financial vulnerability of risk bearers (households or the government) in Iran, a general structure of insurance systems can be proposed and are shown in Figs.4 and 5. In the first proposed insurance system shown in Fig.4 all resources which are normally available after the earthquakes for financing the disaster are included and the insurance coverage would start exactly after the financing gap (critical) year event. This proposed insurance system has three layers: the first layer includes government assistance, the second layer is the insurance cover which covers all the losses after the financing gap year event and the last layer is the residual risk. Another proposed financing system which can be potentially viable for Iran (see Fig.5), has a separated insurance system in which the households don't rely on government assistance. In this insurance scheme, there are three layers which includes a deductible, the insurance coverage and again residual risk (the deductible will be paid by households [13]).

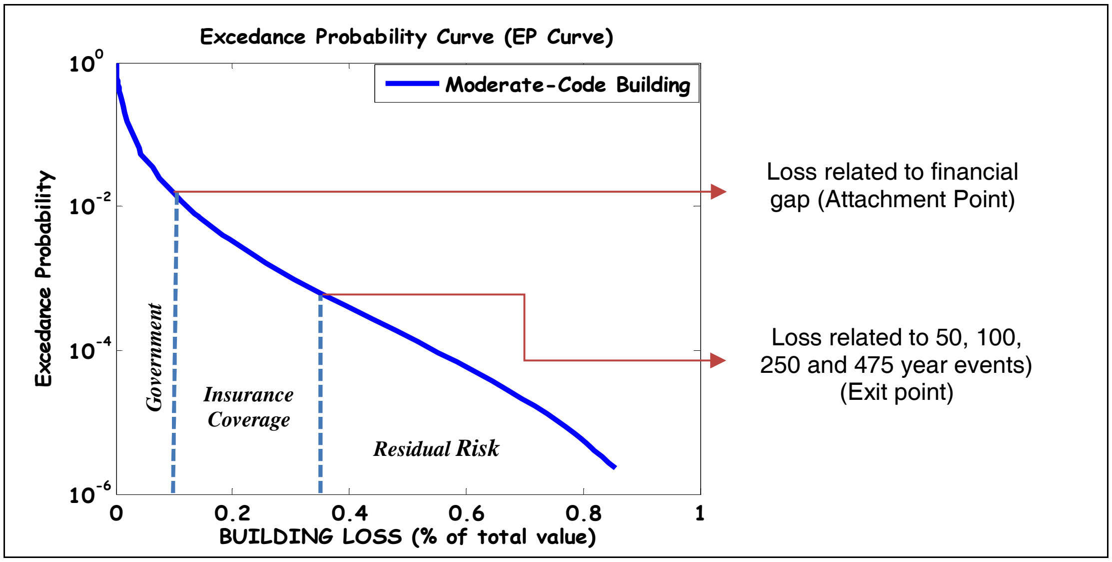


Figure 4. The general structure of the first proposed financing system.

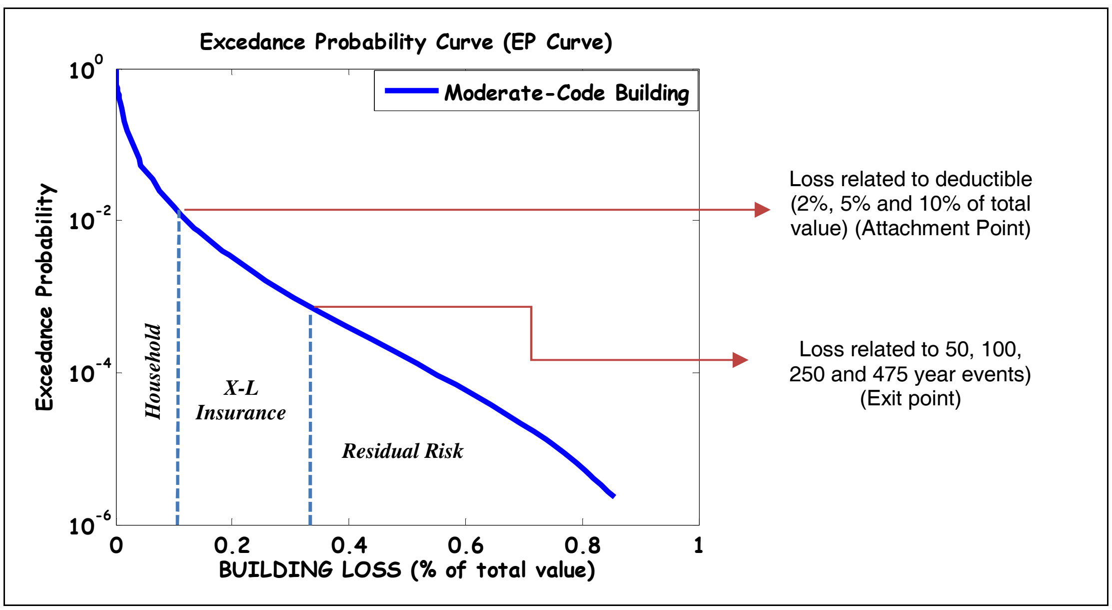


Figure 5. The general structure of the second proposed financing system.

The premium calculations are done assuming actuarial fair as well as loading factor based approaches (see [7]). In the following, we want to examine the affordability of the insurance systems and focus on the first scheme as (due to government assistance) is the cheapest option (for households, not for the government). In order to examine the affordability of risk-based premiums, the average annual income of each household is selected and compared with their corresponding premiums. The maximum claim payment in the current earthquake insurance system which is a part of fire insurance is about 0.45% of average annual income for each household in Shiraz [5]. As current premiums can implicitly compensate a maximum of 50% of the actual losses for a 100 m^2 house, it implicitly (based on the EP curves) can be stated that these maximum loss payments are mostly related to a 250 year event (the design based structure in the Iranian seismic code (2800 standard code) is a 475 year) and therefore could be assumed to be the exit point of the proposed insurance contracts. Table 6 and 7 show the preliminary results for premiums based on percentage of average annual income for each household building types. It is notable that Earthquake Insurance Risk Index for Iranian buildings have been calculated in 2011 [14].

Table 6. Premiums based on percentage of average annual income of each household for the first proposed insurance system.

Types of buildings	Number of stories	Different Exit points											
		Pre-Code				Moderate-Code				High-Code			
		50	100	250	475	50	100	250	475	50	100	250	475
Steel	1-3	16.3	21.1	23.9	26.6	0.0	0.0	1.5	3.2	0.0	0.0	0.0	0.0
	4-7	13.7	18.4	21.3	24.3	0.0	0.0	1.3	2.8	0.0	0.0	0.0	0.0
	> 8	14.6	19.6	22.8	26.1	0.0	2.2	3.7	5.5	0.0	0.0	0.2	1.4
Concrete	1-3	16.3	21.0	23.7	26.2	0.0	0.0	1.5	3.2	0.0	0.0	0.0	0.0
	4-7	14.7	19.4	22.3	25.1	0.0	0.0	1.3	2.9	0.0	0.0	0.0	0.0
	> 8	-	-	-	-	-	-	-	-	0.0	0.0	0.0	1.1
Masonry	1-2	6.2	10.4	12.9	15.3	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0
	3	14.7	19.0	21.4	23.7	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0

(-) there is no building with defined features.

In table 6 almost all numbers for the high-code buildings and also partly for the moderate-code buildings for 50 and 100 year event exit points are zero (mostly because they do not need insurance based on their financial vulnerability). For moderate-code buildings with 250 and 475 year events as exit points, the premiums rates are between 1 and 6 percent and therefore already rather expensive. Most of the premiums for pre-code buildings are more than 10 percent of annual income and therefore can be seen as un-affordable for this household group. The range of the numbers for moderate-code buildings is significantly less than the pre-code buildings. For example, premiums for 1 to 3 story, pre-code steel structures with 475 year event exit point is 26.6 but for the moderate-code one is only 3.2. This indicates that the building code or year of construction is the most important single component which can change the losses and premiums drastically. Consequently, structural mitigation can greatly reduce costs and therefore should be analyzed in combination with financial risk instruments such as the insurance schemes presented here.

Conclusions

We analyzed possible insurance schemes for Iran based on a probabilistic framework which included the financial vulnerability of risk bearers. Critical return periods for pre-code and moderate code buildings are found to be very small which means that households are highly financial vulnerable. The results are mainly driven due to the high structural vulnerability of these structures. In this group, even with government assistance most households are at high risk and even more troublesome, the premiums in percentage of total household income are very high and mostly unaffordable. Consequently, there is need to think about innovative ways to decrease premiums. Options could range from subsidizing premiums to strategies which pool independent risks over Iran (similar to the Caribbean Catastrophe Insurance Facility, CCRIF). However, while the former may cause market distortions the later may be difficult to establish if risks are correlated over different regions too much. One other promising option could be to link premiums with structural mitigation efforts. As shown in [6], mitigation measures could greatly reduce structural risk and therefore could also lower premiums to affordable levels. This could also enable to switch the importance of government assistance (as in the proposed insurance scheme one) to more market based ones (as proposed in insurance scheme two). More analysis is needed to combine these two approaches and to detect best options under limited amount of budgets. Nevertheless, the approach presented here could be a promising way forward to incorporate risk reduction and risk financing within a holistic risk-based framework which is of high importance within current policy discussions in Iran on how to reduce effectively the vulnerability to earthquake risk.

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