Testing of a probabilistic model of seismic risk in China to enable micro-insurance viability and promote mitigation

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ABSTRACT :

Index-based insurance has been recognised as a means to increase the viability of micro-insurance systems. In agriculture insurance, such schemes have already been tested successfully (Levin, 2007 et al.). In index-based schemes loss payouts to farmers are based on an index calculated from a measureable parameter, such as rainfall, that is correlated to the loss experienced, rather than on individual losses. One of the greatest challenges of index-based insurance is defining parameters that are highly correlated with loss, in order to reduce the differential between the payouts to the insured and the individual loss experienced, also known as basis risk.
This paper shows the strengths of a probabilistic earthquake loss model used as a tool to design an index-based earthquake insurance product in China, particularly for homeowners micro-insurance where the high resolution model can reduce basis risk. For an example location, with a portfolio of buildings, loss payouts are modelled based on parameters of earthquake magnitude and distance, providing fundamental metrics to design indexed payout structure. The pure premium is also computed and reflects the risk, as an average annual loss and allows pricing of the risk. The same metrics are also generated for buildings with improved seismic resistance showing how index-based insurance can be used to promote mitigation. This study brings tools and a framework for risk quantification which complements existing studies on the implementation challenges by the growing micro-insurance community.

KEYWORDS: Parametric, earthquake, micro-insurance, mitigation, China

1. INDEX-BASED PARAMETRIC INSURANCE PRODUCTS

Index-based parametric insurance products differ from indemnity-based products in how the loss payout is determined. In an index-based product, the payout is directly linked to a measured parameter that describes the event, such as the size and location. In the case of an earthquake risk for example, a simple parametric trigger could be defined on the basis of earthquake moment magnitude, depth and distance from the insured location. An index is derived for significant events and used to determine the payout that will be made to the homeowner. No claim is filed; no loss adjustment is carried out.
Advantages of index insurance in the context of disaster micro-insurance are the low administrative costs associated with the settling of claims, the reduced moral hazard and adverse selection, and importantly the rapidity of the loss settlement. This has large benefits restoring the livelihood of affected homeowners. Products already exist on the market for agriculture insurance, and their implementation, has spawned interest in exploring the possibilities of index insurance in the broader disaster insurance realm (Mechler et al. 2006, Levin et al. 2007).

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2. PROBABILISTIC LOSS MODELLING: MEASURING THE EARTHQUAKE RISK IN CHINA

When losses occur frequently and loss data is available over a significant length of time, actuarial models can be used to understand the likelihood of loss and develop indices that reasonably correlate physical parameters of a natural phenomenon to the damage experienced. This cannot be said for earthquakes, which can be infrequent and severe. The insurance industry has been using probabilistic loss models for over 20 years to understand catastrophe risk. Two papers in the conference present the features of the RMS China Earthquake Model developed jointly by Risk Management Solutions based in Newark, California and the Institute of Engineering Mechanics in Harbin, China (Wang, 2008; Rahnama, 2008).

Model components

Earthquake catastrophe models are broken down into distinct components, each representing an aspect of the physical behaviour that leads to the damage experienced by a building in an earthquake. In the seismicity model, tens of thousands of possible are defined by the location, magnitude and frequency, and consolidated in a stochastic event set. The hazard component calculates the shaking at individual locations from each of the events. The vulnerability component quantifies the damage to different types of structures, measured as a percentage of the reconstruction cost. The final component of the model is a financial engine which integrates the losses over all the structures in the exposure set, and the events in the model. The model outputs commonly used include the losses at a range of return periods and the pure premium, a measure of the average annual loss, for a single or portfolio of locations.

Selecting a test area: Shandong Province

The map in Figure 1 shows the area of Shandong Province which contains the test location to generate a parametric payout table using the loss model. Shandong is a relevant example, as it is an area of significant seismic risk and has experienced an historic M8 earthquake in 1668. Shandong is also an economic powerhouse, ranked 2nd by GDP amongst China’s provinces in 2006, surpassed only by Guangdong.

The model output shown in Figure 1 is the Loss Cost, the pure premium of a residential type exposure, normalised to the value of the exposure itself. Though this is a meaningful measure of the seismic hazard, it does not provide the metrics that allow the development of an index that determines payouts to individual locations, given the occurrence of an event. The section that follows will describe how the loss model is leveraged to derive the suite of loss estimates that can be used to price risk and design a payout index.

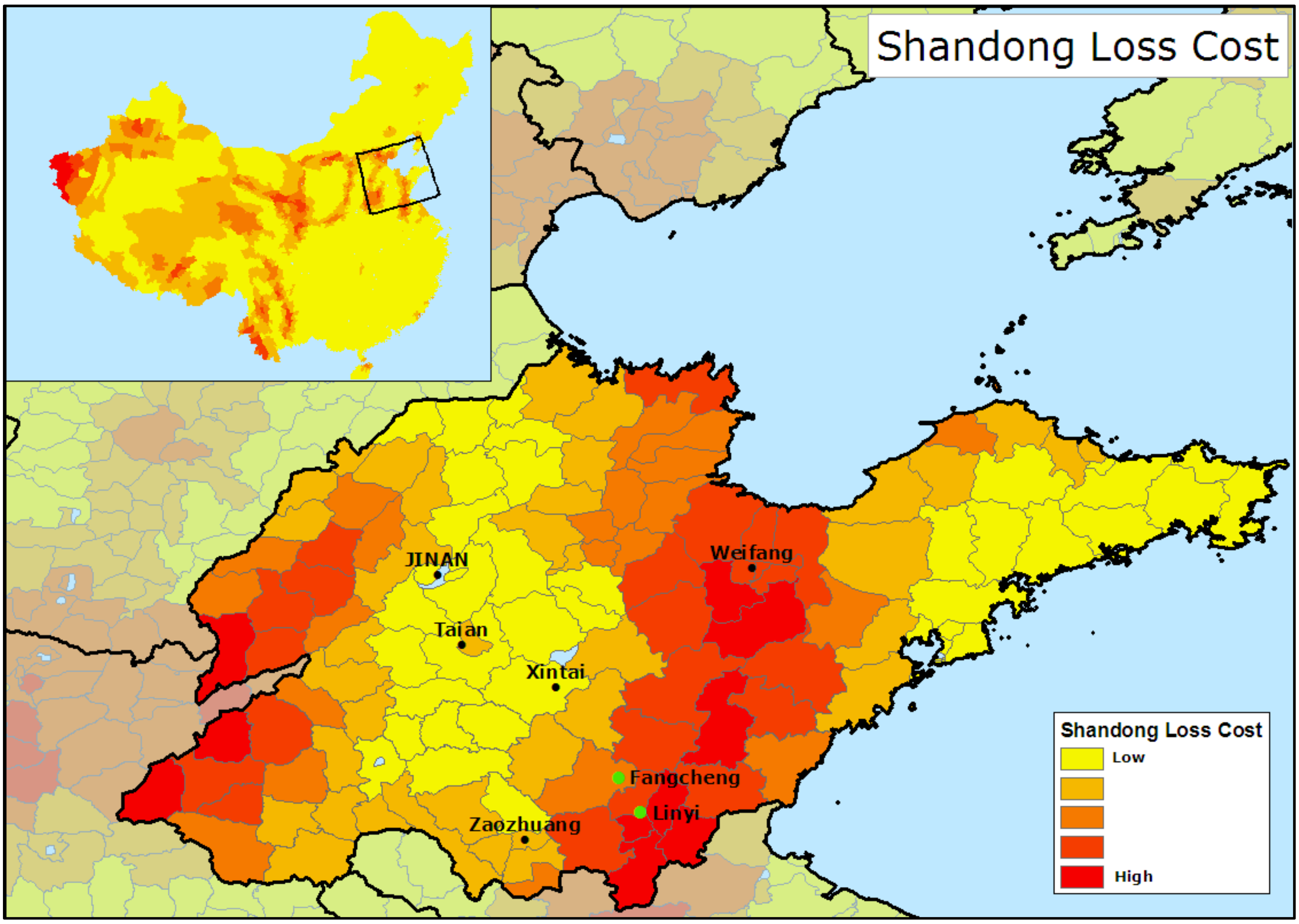

Figure 1 Results from the RMS China EQ model: Loss Cost map of Shandong with China inset

4. DEVELOPING A PARAMETRIC PAYOUT STRUCTURE

Existing Earthquake Parametric Insurance Vehicles

The use of parametric indices to transfer property earthquake risk is not a new concept and has been used by corporate bodies and insurers for many years; numerous catastrophe securitizations of earthquake risk have been successfully placed. The subject exposures of the majority of these are highly diverse and geographical disparate portfolios and thus require a differently structured solution to that needed for earthquake micro-insurance. However some of these securitizations transfer the risk of concentrated exposures thus providing a framework for potential parametric micro-insurance solutions aimed at homeowners.

In these existing insurance structures, a payment is triggered if an earthquake with specific parameters occurs within a pre-defined geographic zone. The amount of payment often depends on the magnitude of the earthquake and in which zone the epicentre occurred, and is set on the basis of catastrophe model output, to reflect the insured's underlying exposures and reduce their basis risk. A similar "catastrophe-in-a-box" methodology can be used as a framework to structure micro-insurance in China, or indeed elsewhere where population exposed to quake risk would benefit from the protection of affordable insurance.

Application to the Chinese Micro-insurance Market – a Case Study

As discussed in section 3, Shandong province makes an ideal test area for any solution. A small hamlet, representing a portfolio of insured buildings, is used as a sample location (sited at 35.289°N and 118.190°E),

near to the village of Fangcheng (marked on Figure 1).
The study carried out here uses the RMS China Earthquake model in two distinct ways, to derive two sets of metrics that are key to a viable insurance product. Firstly the risk analysis is carried out of the test location to calculate the pure premium, which can form the basis to price the premium paid by the insured. This calculation uses all the components of the loss model, including the probabilistic seismicity model. The second part of the analysis addresses the data needed to derive a payout structure, in the event that an earthquake should occur. All earthquakes that could cause a loss must be considered at this stage, as the payouts must be precompiled. Although the RMS China Earthquake Model contains over 75,000 events, the location of the events follows irregular seismic belts and would not offer a homogenous grid, a feature that would simplify the design of an index-based payout structure. The first step in creating a parametric "catastrophe-in-a-box solution" is to define the boxes. A square grid of 676 10km-by-10km boxes (see figure 2) was created with the sample hamlet at the centre. Earthquake epicentres are defined at the centre of each of these boxes. Events of varying magnitude were then simulated at each of these epicentres and the expected loss at the sample location calculated.

Figure 2 shows the variation with earthquake location in Mean Damage Ratios (MDRs), the ratio of expected reconstruction cost to replacement value, to residential stock at the sample hamlet. In this instance, the effects of M7.5 earthquakes are shown, but the extension to a wider range of magnitudes and earthquake properties is apparent. The circular asymmetry in the modelled MDRs is partly due to variations in assumed earthquake fault orientation. In order to calculate the payout due to the insured, the MDR is simply multiplied by the replacement value of the property.

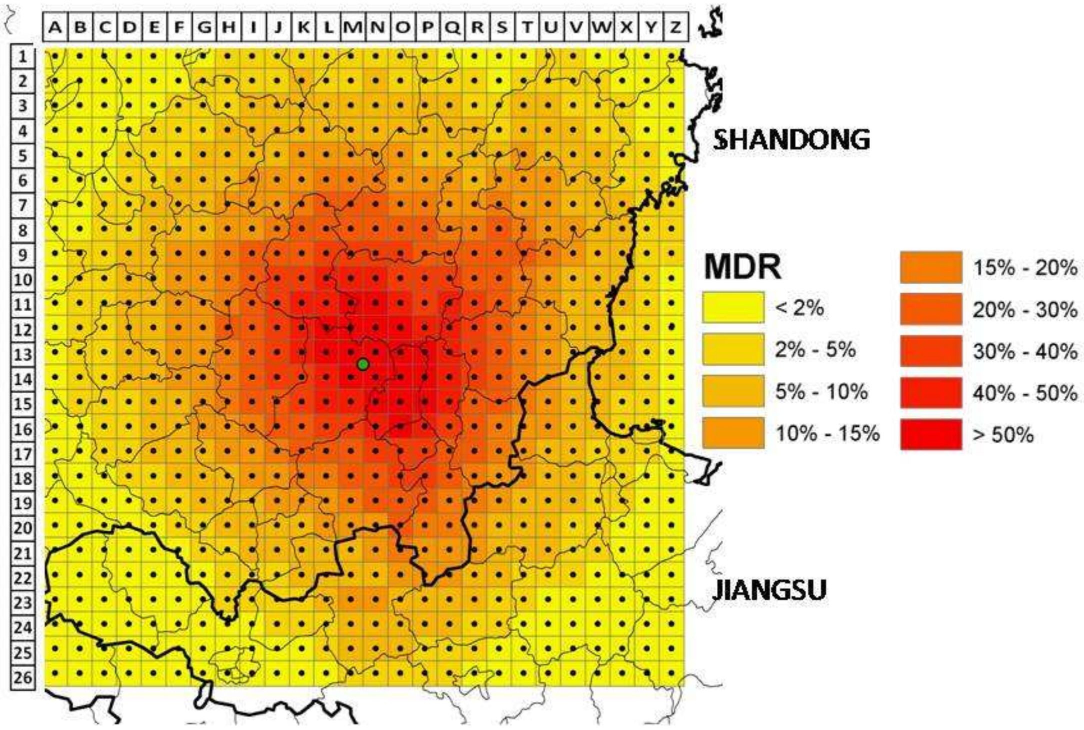

Figure 2: Variation of modelled Mean Damage Ratio (MDR) experienced by the sample hamlet (represented as the green circle), as caused by M 7.5 earthquakes (represented as the black circles) in each of the parametric-index boxes.

The magnitudes of these earthquakes were varied so that an expected loss was calculated for the full spectrum of possible earthquakes within each box. These data were then used to construct a payout table which gives the payment due to the insured, as a result of an earthquake of a given magnitude occurring within a given box.

Figure 3 shows sections of the payout tables for the sample hamlet (RMB 700,000 of residential stock). In the event a M7.0 occurred in box R:9 they would receive RMB 85,000, whilst a M8.0 earthquake occurring in box S:10 would payout RMB 240,000. The full tables contain payout amounts for each of the 676 boxes, and for earthquake magnitudes ranging from M6.0 to M9.0 in M0.1 intervals.

Box		R	S	T	
		…	…	…	
9	…	85	78	73	…
10	…	91	83	77	…
11	…	100	88	83	…
M 7.0		…	…	…	

Box		R	S	T	
		…	…	…	
9	…	245	226	212	…
10	…	262	240	222	…
11	…	290	255	241	…
M8.0		…	…	…	

Figure 3: Extracts from payout tables for the sample hamlet for M7.0 and M8.0 earthquakes. Refer to Fig. 2 for grid coordinates. All payouts are given in thousands of RMB.

A simple micro-insurance contract

The solution outlined above, in which the payout in the event of an earthquake is determined from payout tables, can be applied to any location in China. Variations in local building conditions and in the relative proportions of residential, commercial, industrial and agricultural lines of business can be handled explicitly in the modelling process. Thus this parametric solution has the flexibility to be applied dynamically; by updating the payout details based upon changes in the insured property. As an example, figure 4 shows how a portfolio of micro-insurance contracts for the sample hamlet could evolve on an annual basis as the hamlet changes. One example of a possible payout is given, for the case of a M8.0 earthquake in box S:10. To begin with, in year 1, 10 houses with construction classed as unreinforced masonry (UrM) worth RMB 70,000 each and 2 commercial premises made of reinforced concrete (RC) worth RMB 100,000 each are participating in the scheme. By year 2, all of the UrM houses have been strengthened or replaced with confined masonry (CM). A revised risk analysis will result in a reduced pure premium and, similarily, the modelled payout is reduced for a M8.0 event reported in box S:10.

Year	**1**	**2**
Insured Properties	10 UrM Houses 2 RC Commercial Premises	10 CM Houses 2 RC Commercial Premises
Insured Value	RMB 900,000	RMB 900,000
Change from previous year	-	Strengthening of residential stock
Pure Premium	RMB 1,083	RMB 669
Payout if M8 earthquake in box S:10 (standard deviation)	RMB 355,349 (138,040)	RMB 246,507 (121,970)

Figure 4: Case study detailing how a micro-insurance program for the sample hamlet may evolve.

5. BASIS RISK REDUCTION AND OTHER BENEFITS OF ANALYTICAL MODELLING

The tables in the previous section show an example of a parametric payout table of modelled loss estimates, using earthquake location and magnitude as parameters. How can this data be used to determine a precompiled payout structure used in an insurance contract? One way is to extend this table to create a large look-up matrix of MDRs, for each location, which would be consulted after an event to see if the earthquake triggers the payout, and what the payout sum would be. The damage ratios would vary by location and magnitude of the earthquakes, but also by building characteristics such as construction class, age of construction and building height. Damage rations could also vary by line of business and coverage types (buildings, contents and business interruption). Another approach would be to create indices, in the form of equations that determine the payout based on selected the best fit with the data generated in the payout table of modelled losses. In this paper we do not set out to design a payout structure; the broader context of the insurance product design will inform which of these two, or other solutions would best suit the product. By presenting sample losses from a payout table we show that a high resolution loss model offers the insurance company a breadth of options. The product design can reduce basis risk. Firstly this could be achieved in the hazard component, the “catastrophe-in-the-box” for example by optimising the size of the grid and the resolution of the payout locations. Secondly, accounting for difference in precompiled payout in relation to the seismic vulnerability of the building. The loss models contain vulnerability functions for all principles construction classes and, also modified according to the age and height of the building.

Models continue to improve in their accuracy, as we learn from real earthquake events and advances in engineering sophistication. Residual uncertainty around the modelled result will remain and must be included in the design considerations of the payout structure. In particular the insurer will be interested in interrogating the model to understand how the uncertainty in the total payout losses changes with portfolio size and distribution.

Index insurance supports mitigation

Insurance systems have been identified as means of promoting mitigation measures, such as seismic strengthening to properties (Kunreuther, 2000). Because of the greater resistance to earthquake damage, the expected loss is reduced and this saving can be passed down to the insured in the form of lower premiums. One of the first challenges is to prove the cost-benefit of mitigation through the quantification of the real reduction in risk, the other is give the homeowner the incentive to carry out the building works, or to ensure the compliance to building codes of new buildings. On the first point, engineering-based loss models can be used to quantify the net reduction in risk following strengthening works, as demonstrated in the previous section. However, there has been less reported success on the second point, and observers are looking at index insurance with interest to create the framework to encourage the execution of mitigation strategies.

Figure 3 in the previous section, has shown how the index and pure premium can reflect the reduced risk thanks to mitigation and improvement of building stock. In the context of index insurance, these metrics become particularly significant. Index insurance has promising perspectives for encouraging mitigation. It is a known fact that index contracts reduce the moral hazard to insurers. In crop failure insurance for example, the farmer with index-based insurance has the same economic incentives to harvest a profitable crop as a non-insured farmer. Payouts are not based on individual losses but on indexed losses, so managing the harvest effectively in adverse weather conditions that could trigger a payout could result in payouts even though little or no loss was experienced. This situation can be translated to building insurance for earthquake risk. A homeowner insured under an index-based contract could see the benefit of reduced premium and become more likely to receive an index-based payout in excess of the real loss experienced if the seismic resistance exceeds that assumed in the index design.

Insurance for the bottom of the pyramid

The unique structure of index-based insurance make it particularly suitable for low income customers in emerging economies; the so-called bottom of the pyramid (BOP). Index based insurance products tick many of the twelve principles of innovation identified by C.K. Prahalad (Prahalad, 2006) that are required to penetrate in BOP market. It is technologically intense and requires education and information sharing between the insurers and the insured. Success stories from business' in BOP markets have demonstrated the speed at which this market embraces information technology. A robust index insurance contract, which is transparent and consistently enforced, adds another building block towards creating what Prahalad calls the Transaction Governance Capacity, "the capacity of a society to guarantee transparency in the process of economic transactions". The insured is an active agent in this contract as the transparency of the index would allow the use of information technology to query the index structure, understand the reduced premiums resulting from improved building standards and monitor payout triggering.

6. CONCLUSION

This paper has shown that a probabilistic earthquake model that quantifies the loss to properties from earthquake risk in China can be leveraged by organisations to develop earthquake disaster insurance products aimed at homeowners in China of all ranges of income, including the most disadvantaged and vulnerable at the bottom of the pyramid. Underlying the insurance scheme with a model that is already used in the global reinsurance market has the added advantage that the common platform creates single transparent currency to transfer risk. This gives confidence that a growing insurance scheme with high penetration and accumulations with correlated risk can be placed competitively on the global market.

The model has been tested using a "catastrophe-in-a-box" method to show how loss metrics can be derived to populate a payout table. Using the example of a hamlet in Shandong province, the results have shown that the losses can capture the differences in construction classes and seismic resistance. The high resolution loss analytics and the contractual transparency possible through index insurance offer the best opportunity for engagement with the insured to promote mitigation though building strengthening and building code enforcement. The long term implications to the overall reduction of physical loss could be far-reaching.

This paper has mainly concerned itself with the quantification of the risk, and showcasing the tools that can be used to reduce the basis risk in index-based insurance. No matter how sophisticated the models become in reducing the uncertainty, and indexes at reducing the basis risk, there will always remain some uncertainty in the modelled losses, and an insured might not receive a payout commensurate to the loss experienced. Risk pooling, where groups of individuals share the risk, has been identified as one way of spreading any disparity in the payouts due to basis risk (Levin et al. 2007). This, contemplated for agriculture index insurance, should also be considered for earthquake insurance

There is a wealth of literature on other implementation challenges, such as distribution across the large geographies of China (Liu, 2008). In a paper for this conference Coburn and Winchester (2008) point to the use of successful micro-finance schemes to leverage social networks, whilst Gordon Woo (2008) addresses the affordability issue by looking at the external support towards premium payments offered by remittances from emigrated relatives and friends. Linking the analytics available to quantify losses to other aspects of the implementation of insurance in vulnerable societies will strengthen the holistic view of disaster insurance as a product, designed to meet a need in the market and hasten the recovery of homeowners stricken by disaster.

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