

# Insuring against earthquakes: simulating the cost-effectiveness of disaster preparedness

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*Ex-ante measures to improve risk preparedness for natural disasters are generally considered to be more effective than ex-post measures. Nevertheless, most resources are allocated after an event in geographical areas that are vulnerable to natural disasters. This paper analyses the cost-effectiveness of ex-ante adaptation measures in the wake of earthquakes and provides an assessment of the future role of private and public agencies in disaster risk management. The study uses a simulation model approach to evaluate consumption losses after earthquakes under different scenarios of intervention. Particular attention is given to the role of activity diversification measures in enhancing disaster preparedness and the contributions of (targeted) microcredit and education programmes for reconstruction following a disaster. Whereas the former measures are far more cost-effective, missing markets and perverse incentives tend to make ex-post measures a preferred option, thus occasioning underinvestment in ex-ante adaptation initiatives.*

**Keywords:** cost-effectiveness, disaster preparedness, earthquakes, insurance, simulation approach

## Introduction

Natural hazards may become natural disasters either because of action or because of a lack of action by humankind. Natural hazards are physical events that happen due to (mostly unforeseen) acts of nature, such as a drought, earthquake, flood or tsunami. Natural disasters only happen when the natural hazard has serious negative consequences for people's livelihoods. A natural hazard is a necessary but not a sufficient condition for the occurrence of a natural disaster.

Private and public agencies can act to reduce the disastrous effects of natural hazards, relying on ex-ante or ex-post measures or a combination of both. In the past, relief agencies have mainly acted ex-post and in a reactive manner to natural disasters. One can divide ex-ante measures to minimise the adverse effects of natural hazards into two main categories:

- adaptation measures, which are focused on the restructuring of the local society and livelihood strategies, moving away from disaster-prone activities through upgrading of the physical and social infrastructure to withstand the impacts of disasters (Freeman, Keen and Mani, 2003); and

- mitigation measures, which intend to reduce the risk of adverse weather events (Heller and Mani, 2002).

Recent studies point to the need for more *ex-ante* measures (Andersen, 2005; Skoufias, 2003; Christoplos, Mitchell and Liljelund, 2001), arguing that such measures to enhance risk preparedness after natural disasters are generally considered more cost-effective than *ex-post* measures in the form of emergency relief. Since many agencies still act mainly in response to natural disasters, questions are raised regarding the perceived cost-effectiveness of disaster mitigation and preparedness: ‘[d]espite the seemingly glaring need to reduce the horrific impact of floods droughts and wars, disaster mitigation and preparedness have neither the allure of directly “saving lives”, nor of providing an “escape from poverty”’ (Christoplos, Mitchell and Liljelund, 2001, p. 188).

This paper addresses why governments and non-governmental organisations (NGOs) continue to focus more on disaster relief and to underinvest in risk preparedness measures. A key explanation for the lack of *ex-ante* investment in disaster mitigation and adaptation could be perverse incentives. Governments of countries that are affected regularly by natural disasters move to anticipate the availability of *ex-post* finance, exactly because *ex-post* support has always been given in the past. Hofman and Brukoff (2006) argue that anticipation of external assistance may be an important factor in explaining why countries tend to underinsure for disaster risks. The moral difficulty of donors in withholding support after an event may diminish because of *ex-ante* disaster mitigation and adaptation.

The preference of aid agencies to respond *ex-post* to natural disasters is likely to be provoked by market and information constraints that undervalue disaster mitigation and preparedness measures. In part, this might be explained by incentives within the current aid architecture, since preparations for disasters might lessen prospects for receiving emergency relief support once a natural disaster occurs. Recent innovations in the disaster risk insurance market could be helpful in reducing such perverse incentives. With the emission of catastrophe bonds and other index-based insurance products (Skees, Barnett and Murphy, 2007a; Skees, Hartell and Murphy, 2007b) disaster risk insurance has become much easier. *Ex-ante* adaptation measures are therefore expected to play a more prominent role in the near future, given the positive linkages between credit and insurance markets (Skees and Hartel, 2006).

We need to know first, however, whether *ex-ante* measures for disaster risk management are indeed more cost-effective than *ex-post* measures for disaster relief. Quantitative evidence on the perceived cost-effectiveness of *ex-ante* measures is still scarce. The aim of this paper is to contribute to the debate on the effectiveness of *ex-ante* measures to guard against natural disasters, wherein we examine the case of earthquakes. We used a simulation model to estimate the impact of (a) micro-credit and education programmes on inter-sectoral diversification and (b) inter-sectoral diversification on consumption losses after an earthquake. One can consider these long-term development measures as risk mitigation devices and adaptation

measures that may be more effective than monitoring procedures. Microcredit and education, though, should be targeted at the right groups to be effective in adapting to disasters.

Disaster reconstruction and recovery measures tend to be less effective at enhancing resilience to earthquakes. Countries and households that do not invest sufficiently in ex-ante measures are likely to suffer more from shocks. This underinvestment can be explained by perverse incentives forthcoming from market failures in the disaster risk insurance market. Policies that offset these perverse incentives thus could enhance the adoption of ex-ante adaptation measures in the short run. However, innovations in the disaster risk insurance market act as substitutes for ex-ante adaptation measures in the long term and are not fully complementary in the farther future. Our model results provide empirical evidence for decreasing diversification benefits when insurance markets are better developed.

The remainder of the paper is structured as follows: first, it reviews the different theoretical arguments for ex-ante disaster mitigation and adaptation or ex-post emergency relief actions. Next, it presents the stylised analytical model designed to estimate and compare the cost-effectiveness of ex-ante and ex-post measures. This is followed by the presentation of the empirical results of several model runs of consumption expenditures after a simulated earthquake. These results are discussed subsequently against the backdrop of national governance structures and international aid policies that are likely to occasion market and information failures. The study contends that the current bias in favour of ex-post measures can be largely explained by such perverse incentives. Finally, the paper looks at the possible role of NGO involvement in disaster risk insurance in the future. Even while emergency relief measures will remain necessary, a shift towards ex-ante adaptation measures and disaster risk insurance will increase resilience to earthquakes.

## **Effectiveness of disaster preparedness**

Several earlier studies have addressed the motives for and the perceived effectiveness of disaster mitigation investments to stabilise consumption, health or income. Owens, Hoddinott and Kinsey (2003) analyse the cost-effectiveness of ex-ante measures versus ex-post measures in relation to the drought experienced in Zimbabwe in 1994–95. The government responded with an ex-post programme of grain loans. Using detailed panel data, a simulation model was constructed, wherein the effects of the grain loan scheme were compared with the effects of hypothetical combinations of ex-ante and ex-post aid. The study demonstrates that programmes with more ex-ante aid would have been far more cost-effective. In a similar vein, Hoddinott and Kinsey (2000, 2001) show that private ex-ante adaptation measures were also far more effective in mitigating the impacts of the drought on human health. Livestock could be used successfully as a buffer to decrease the ramifications of the drought shock on the health of women and children. Increasing the value of livestock owned by women thus could be helpful in maintaining their body mass index.

Current discussions on disaster risk management tend to focus attention on the available options for enhancing household-level resilience. Studies in semi-arid areas of India indicate that local risk-sharing mechanisms are quite capable of controlling consumption losses faced after idiosyncratic (that is, individual) shocks (Townsend, 1994). These findings, however, are challenged by other research using the same data, indicating that such risk insurance is limited to certain social segments of society (Ravallion and Chaudhuri, 1997). Carter and Maluccio (2003) provide similar evidence in their study of differences in strategies to cope with stochastic weather shocks among communities in South Africa, showing that insurance against risks is strongly related to the stock of community social capital.

Several instruments are commonly forwarded as appropriate strategies to augment disaster risk management. Microcredit has become a popular tool for enabling ex-post recovery investments, and is increasingly considered also as an insurance device that could boost the adoption of ex-ante risk adaptation measures (Udry, 1990). In the latter case, households may be entitled to diversify their activity portfolio and hence reduce their vulnerability to specific shocks. Credit is critical for meeting the sunk costs required for engagement in other activities. Education is an important complementary device for activity diversification, since knowledge and management abilities are needed to become successful in non-traditional sectors. Education also enhances willingness to invest and tends to reduce risk averseness of households at low-income levels (Feder, Just and Zilberman, 1985).

The macro-policy environment strongly influences the selection of appropriate disaster risk-management strategies. Detailed case studies of disaster reconstruction and recovery in different settings illustrate that public efforts tend to be of limited effectiveness (Jalali, 2002; Ozerdem and Barakat, 2000; Bamforth and Qureshi, 2007) due to political complexities and numerous institutional constraints. Inam (1999) clearly shows that disaster reconstruction and recovery requires an environment with high quality and reliable institutions. Formal insurance can substitute for ex-ante adaptation measures in the long run, and innovations in disaster risk insurance markets may actually even crowd out ex-ante disaster preparedness policies. The main challenge seems to be to safeguard effective cooperation and linkages between formal disaster relief efforts and informal insurance mechanisms at the local/community level. Therefore, financial mechanisms and institutional regimes need to be tailored to the requirements of balancing investments in ex-ante risk adaptations to guarantee preparedness without losing ex-post access to reconstruction resources.

## **Estimating consumption loss after earthquakes**

Diversification of activities can reduce the socioeconomic impact of shocks. Specialised economies tend to experience larger consumption losses due to natural disasters than more diversified economies (Skoufias, 2003). Diversification is an endogenous process that policy can influence. Such diversification policies can stabilise welfare, even when market failures lead to underinvestment.<sup>1</sup> A model derived from country

panel data does indeed provide evidence that more specialised economies tend to experience larger consumption losses after earthquakes (Ramcharan, 2005). Evidence from a field study in El Salvador demonstrates that investments in education and micro-credit provision can be particularly helpful in enhancing diversification (Tannuri-Pianto et al., 2005). Addressing recurrent problems on the capital market and in education thus might be an option to compensate for underinvestment in direct diversification efforts. Combining and calibrating the parameters from the two aforementioned studies, we are able to estimate the welfare effects under different scenarios of activity diversification in countries with a high level of vulnerability to earthquake activity.

Three economic sectors are distinguished:

- the traditional agricultural sector (subsistence food crops);
- the modern agricultural sector (export crops); and
- the non-agricultural sector.

Only diversification into non-agricultural activities could lead to mitigation of consumption losses caused by an earthquake. For each year that an earthquake could occur after the introduction of the mitigation policies, the distribution of labour across sectors can be estimated using Gini coefficients as an indicator of diversification across sectors.<sup>2</sup> In the base year, each household has a 33.3 per cent chance of being active in one of the three sectors. A multinomial logit model, derived from the original study, is used to estimate transition probabilities.<sup>3</sup> Table 1 shows the explanatory variables and parameters of the original study.

With the help of the base-year activity distribution and the transition probabilities, we can estimate the chances of working in each of the three sectors in subsequent years. This is possible for five different types of households (subdivided according to the intrinsic characteristics in Table 1), given the equal base year distribution at  $t = 0$  as shown in equation 1:

**Table 1** Determinants of inter-sectoral diversification

Households characteristics	Coefficient Non-traditional agriculture	Coefficient Non-agriculture
Non-traditional agriculture initial (year $t_{-1}$ )	4.025	0.913
Non-agriculture initial (year $t_{-1}$ )	0.905	8.294
Education of household head	1.245	1.037
Regular access to credit (ex ante)	0.539	0.515
New access to credit (ex post)	2.074	0.855
Education and regular credit access	1.039	1.027
Education and new credit access	0.801	1.004

**Note:** traditional agricultural sector is the reference category.

**Source:** Tannuri-Pianto et al., 2005.

$$\Pr(Y_{it} = j) = \frac{e^{\beta^j x_i}}{\sum_{k=0}^2 e^{\beta^k x_i}} \quad j=0,1,2; t=0, 1, \dots, n. \tag{1}$$

where  $j$  = sector (0 = traditional agricultural sector, 1 = non-traditional agricultural sector and 2 = non-agricultural sector) and  $x_i$  = explanatory household characteristics. We use the household characteristics and the parameters from the model to predict the likelihood of engagement in the same or another economic sector.

After estimating these chances, we calculate the Gini coefficients for inter-sectoral diversification and introduce exogenous shocks in the form of earthquakes to the model. Table 2 is derived from an original panel data model for consumption losses after earthquakes and shows that a one-point increase in the Gini coefficient leads to a 20-point rise in consumption loss in the year after the earthquake.

Consumption loss after earthquakes for different scenarios is estimated as described in equation 2:

$$\Delta C = -20.462 * E(GC) \tag{2}$$

where  $\Delta C$  is the consumption loss after the occurrence of earthquakes, and  $E(GC)$  is the Gini coefficient (derived from the changes in the proportional distribution of the labour force across sectors, as calculated with equation 1).

The model for consumption loss after earthquakes is estimated with the help of data on earthquakes from the Center for Research on the Epidemiology of Disasters (CREDES). An earthquake event is reported according to the following conditions:

- 10 or more reported people killed;
- at least 100 people reported affected;
- a call for international assistance; and
- a declaration of a state of emergency (Ramcharan, 2005).

**Table 2** Ordinary least squares: change in household consumption in the year after an earthquake

Variable	Coefficient	Huber-White Standard Error
Gini Coefficient	-20.462	11.511
Per capita income	0.154	0.395
Population density	7.836	16.002
Log of population size	-0.018	0.069
Year dummies	Included	–
Fixed effects	Included	–
Adjusted R <sup>2</sup>	0.073	–
N	78	–

Source: Ramcharan, 2005.

For the diversification analysis, data from the International Labour Organization (ILO, 2003) on employment shares across sectors were used to calculate a Gini measure of specialisation across sectors. Control variables regarding consumption behaviour in the year before the earthquake include gross domestic product (GDP) per capita and population density. The model also controls for non-linear effects and interactions and is estimated with the help of panel data and fixed effects (including year dummies).

The original multinomial logit model has been estimated with data derived from the rural panel survey conducted by the Fundación Salvadoreña para El Desarrollo Económico y Social (FUSADES) and the Rural Finance Program at Ohio State University. The survey data include information on demographic and occupational characteristics, access to credit and physical assets (such as infrastructure, land and housing) and other characteristics that affect the income dynamics of rural households and their strategies to cope with risk.

The policy analysis grants attention primarily to the effectiveness of programmes for the explanatory variables microcredit and education, which can improve welfare in the long run but can also be helpful in increasing resilience after disasters (Skoufias, 2003). We focus on the latter effects and largely ignore other, long-term development ramifications of microcredit and education programmes. Microcredit only leads to diversification outside agriculture when the recipients are educated or have permanent access to credit. When the recipients are less educated and access to credit is recent, it mostly leads to diversification from traditional agriculture into modern agricultural activities. In such a setting, microcredit might reinforce consumption losses.

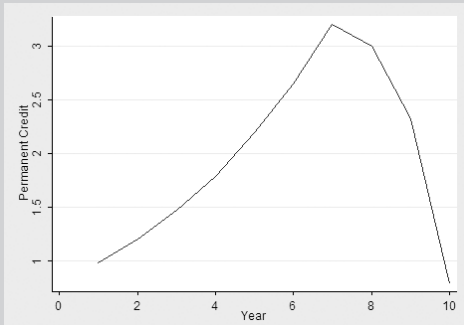
In the first instance, shifts from agriculture to manufacturing might not seem the most straightforward way to decrease vulnerability to earthquakes. However, the latter might decline because of differences in insurance between urban and rural areas. Several authors report the larger difficulty of rural areas insuring themselves against natural disasters (see, for instance, Gaiha and Thapa, 2006). Besides, agricultural production can suffer direct losses as a result of landslides (Perotto-Baldiviezo et al., 2003; Morris et al., 2002; Koi et al., 2008). In this respect, one can consider earthquakes as a general case of a catastrophic natural disaster.

## Results

We used the model described above to analyse the effects of different disaster mitigation policies on household consumption losses after an earthquake, comparing different degrees of activity diversification. Given the changes in consumption occasioned by an increase in sectoral diversification, we can assess the simulated adjustment path for specific types of disaster mitigation policies. Figure 1 shows the results for five different scenarios for consumption over time after the occurrence of an earthquake:

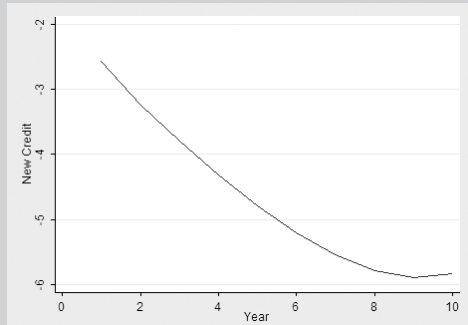
1. households that have permanent access to credit (ex-ante);
2. households that acquire new access to credit and can invest after an earthquake (ex-post);

**Figure 1a** Consumption loss after an earthquake in year  $t$  for households with ex-ante access to credit



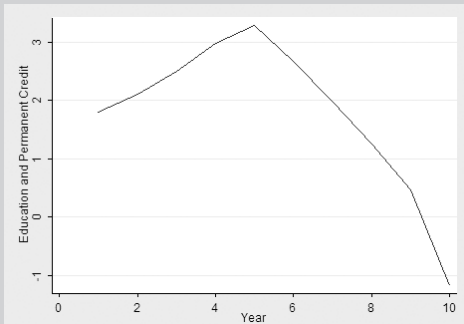
Source: author's calculations.

**Figure 1b** Consumption loss after an earthquake in year  $t$  for households with ex-post access to credit



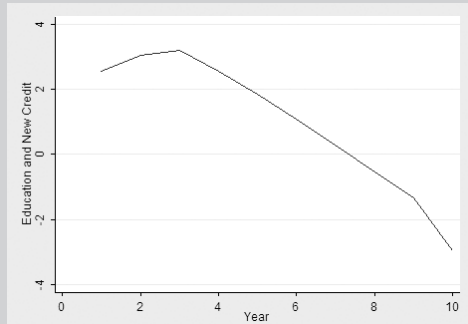
Source: author's calculations.

**Figure 1e** Consumption loss after an earthquake in year  $t$  for households with ex-post access to credit and education



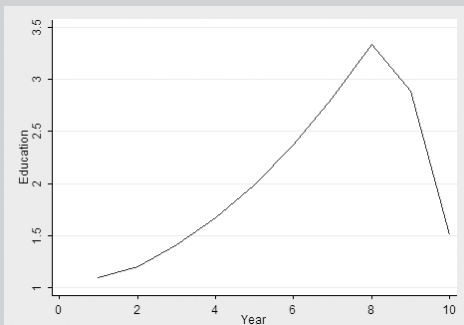
Source: author's calculations.

**Figure 1d** Consumption loss after an earthquake in year  $t$  for households with ex-ante access to credit and education



Source: author's calculations.

**Figure 1c** Consumption loss after an earthquake in year  $t$  for households with education



Source: author's calculations.

3. provision of education to vulnerable households;
4. educated households that have permanent access to credit ( $= 1 + 3$ ); and
5. educated households that get new access to credit and can invest after an earthquake ( $= 2 + 3$ ).

The effects of ex-ante provision of credit on consumption are highly positive compared to ex-post credit access, since the former enables timely activity diversification whereas the latter leads to diversification within sectors and even to higher consumption losses after earthquakes (see Figures 1a and 1b). Provision of education to households also has a positive effect on consumption. The effect is stronger if the time between education and the earthquake increases (see Figure 1c). Combining ex-ante credit provision with ex-post education investments strongly decreases consumption loss, when the earthquake occurs shortly after the intervention. If the earthquake happens long after the intervention, however, this results in larger consumption loss (see Figure 1d). Finally, the implications of ex-post credit provision combined with ex-ante education investments produce similar consumption loss, but at a lower level and with a slightly more delayed payback period (see Figure 1e). In sum, ex-ante credit facilities and education investments generally lead to positive consumption effects (that is, enabling diversification out of agriculture), whereas ex-post credit aftershocks strongly reduce—or even reverse—these effects due to less profitable investment prospects in stagnating agricultural activities.

The model results indicate that ex-ante mitigation measures can be effectively used as an instrument to enhance timely adaptation to disaster risks. This is particularly the case for credit provision that becomes an insurance option to diversify activities to protect against temporary income shortfalls. Education is useful as a complementary device to enable access to non-agricultural activities, especially when available before shocks occur.

## Ex-post measures

That ex-ante risk management measures are found to be effective after certain shocks does not necessarily imply that they are generally more feasible than ex-post measures. The final choice very much depends on the local institutional environment. Ex-post measures may be considered less effective in areas where institutional failures prevail (that is, high corruption or large delivery time lags) that prevent rapid responses to disasters. In such settings, NGOs are likely to play a major role in disaster relief activities.

Emergency assistance is certainly required under such conditions. Pinera, Reed and Njiru (2005) show that efforts to restore housing conditions and sanitation services after the 2003 earthquake in Bam, Iran, have been very effective. Civil-society organisations play a key role in mobilisation after natural disasters, even in countries with low-quality public institutions. Similarly, Jalali (2002) argues that civil-society organisations in Turkey were more effective in delivering ex-post emergency relief

after the 1999 Marmara earthquake than state institutions, although reconstruction suffered extreme delays (Ozerdem and Barakat, 2000). Emergency relief delivery after the 2005 earthquake in Kashmir was severely hindered by the highly politicised environment (Bamforth and Qureshi, 2007). Otherwise, some countries with very tight state control seem to be able to limit human damage immediately after disasters: a country like Cuba has a strong track record in minimising potential mortality and morbidity as a result of hurricanes and tropical cyclones, but a rather poor one in reconstruction and recovery (Benigno, 2005).

Countries with low-quality institutions, however, do experience on average higher death tolls in natural disasters (Escaleras, Anbarci and Register, 2006; Kahn, 2005). This suggests that ex-post emergency relief is more difficult in such an environment, partly due to the politicised nature of humanitarian relief, which complicates coordinated reconstruction and recovery efforts. Cooperation between state and civil-society organisations is essential to guarantee an effective response to earthquakes. Under these conditions, ex-ante risk mitigation measures would be preferred and are likely to be more effective. Even when information on the likelihood of natural disasters is readily available, ex-ante risk preparedness allows one to overcome the usual coordination constraints that appear after the occurrence of the disaster. Since public agencies may be reluctant to invest in risk preparedness, there is clearly room for voluntary organisations and NGOs to undertake such measures.

## **Perverse incentives and innovations in disaster risk insurance**

The general lack of ex-ante measures for disaster risk management may be explained by perverse incentives. Access to ex-post emergency relief may shrink because of ex-ante adaptation measures. Donors tend to believe that emergency relief is no longer needed when investments are made to adapt to disaster losses. Anticipation of external assistance if a disaster were to strike may be an important factor in explaining why (public and private) agencies tend to underinsure for disaster risks (Hofman and Brukoff, 2006).

Disaster risk insurance markets have long suffered from market failures. Even in many developed countries, private catastrophe insurance markets have been significantly reduced (Jaffee and Russell, 1998), due to arguments that the cost of a mega-disaster easily exceeds all available reinsurance capital. This is particularly the case when hedging of catastrophe risks remains inadequate. More innovative catastrophe bonds offer better opportunities for hedging catastrophe risks. Markets for catastrophe bonds transfer a set of risks from the sponsor (donor or reinsurance company) to investors (Hofman, 2007). The return on these investments is paid to the holders of the bonds, together with a premium paid by the sponsors. If the bonds mature without the disaster having taken place, the principal is repaid to the investors. If the disaster does happen, part of the investors claim is transferred to the sponsor, thus

sharing the risk of income shortfalls (Hofman, 2007). Public or international reinsurance may be helpful in reducing the constraints on private-sector participation in developing catastrophe insurance. In addition, public provision of basic infrastructure may be helpful in enhancing the prospects for the operations of private financial agencies. Land titling and feeder-road upgrading are generally considered to be key factors for financial market development.

Catastrophe bonds do secure ex-post relief assistance and thus may decrease the perverse incentives against ex-ante mitigation measures. However, increased insurance against disaster losses could equally lead to a neglect of investments in risk preparedness. In that case, insurance substitutes for risk mitigation measures. As shown in our model simulations, credit availability could enhance adaptation to disasters based on activity diversification as a self-insurance device. This points to the possibility that risk insurance and self-insurance become rather complementary.

Many ex-ante adaptation measures are informal ways to insure against disasters. Activity diversification helps in making risks more idiosyncratic instead of covariate. Idiosyncratic risks increase the opportunity to share risks within communities. Local communities often have customs of transferring resources to the people hurt most by an exogenous shock. This method is only effective when risks are mostly idiosyncratic and not covariate. Consequently, consumption smoothing is made easier because of local risk sharing arrangements (Townsend, 1994).

Coping with natural disasters remains difficult, however, for certain groups in society, particularly when risks are of an idiosyncratic nature. Carter and Maluccio (2003) show that some households in South Africa appear unable to insure against risks, if situated in communities that lack social capital to cope with exogenous weather shocks. The poorest people usually face the most difficulties in finding informal insurance markets. Their vulnerability is closely linked therefore to poverty conditions (Morduch, 1999). Since the poor already face difficulties in staying around the poverty line even before a natural disaster occurs, it will be difficult to transfer resources to other people hurt by the natural disaster. The absence of so-called bridging social capital hinders access by the poorest people to local insurance mechanisms.

Improvements in informal insurance mechanisms thus can be helpful in heightening willingness to engage in formal ex-ante disaster preparedness. Otherwise, formal disaster risk insurance mechanisms also can crowd out informal insurance arrangements and assure wider access to a more efficient insurance system. Although imperfect, formal disaster insurance mechanisms can substitute for socially biased informal insurance mechanisms. Improvements in formal insurance in our model might lead to a shift from ex-post credit (see Figure 1b) to ex-ante credit (see Figure 1a) because of improved credit market access and hence a more effective contribution of microcredit to reduce consumption losses immediately after an earthquake.

Hence, the poor might benefit most from formal insurance mechanisms. Bridging social capital is not a necessary condition for access to formal insurance, whereas it is often required to gain access to informal insurance.

## Outlook and policy implications

This paper provides some experimental evidence regarding the importance and effectiveness of ex-ante disaster adaptation measures. Based on a simulation approach, it appears that activity diversification into other sectors could substantially reduce consumption losses after the occurrence of earthquakes. Diversification within the same sector, however, does not lead to a similar recovery pattern in consumption.

Microcredit and education can prevent consumption losses after earthquakes as a result of their impact on activity diversification. Sectoral diversification mainly takes place because of permanently available microcredit and microcredit provided to educated households. Temporary microcredit provision only enables within-sector diversification, just like the provision of microcredit to uneducated individuals.

Anticipation of external assistance could easily lead to under-investment in ex-ante adaptation measures, due to perverse incentives. Disaster risk insurance can be helpful in reducing this preference for waiting. Recent innovations in the disaster risk insurance market have improved options for engaging in ex-ante disaster preparedness without foregoing the potential benefits of ex-post disaster relief. This may result in stronger commitments by NGOs and governments to invest in ex-ante adaptation measures.

Such ex-ante adaptation measures can be seen as a complement to informal local insurance mechanisms to guard against consumption loss due to natural disasters. We expect, therefore, that households in settings with better-developed financial markets will be able to recover more rapidly after earthquakes. Improvements in insurance markets might even act as a generator of shifts from ex-post to ex-ante initiatives and thus more effective microcredit.

Activity diversification is a suitable informal strategy for self-insurance against consumption losses due to earthquakes. Improving access to markets for risk insurance derivatives may remove the constraints that give rise to under-investment in ex-ante adaptation measures. Otherwise, such a formal insurance mechanism also could crowd out ex-ante adaptation measures. Consequently, it is of fundamental importance to guarantee effective complementarities between formal and informal insurance mechanisms.

Whereas formal insurance and financial services are likely to be provided by private agents (sometimes with public reinsurance), voluntary agencies such as NGOs still play a major role, both in providing emergency relief after disasters and in promoting the adoption of risk adaptation measures. In the last few years, however, the focus on NGOs also has shifted to ex-ante measures. NGOs are particularly effective in putting risk preparedness for natural disasters on the policy agenda (Matin and Taher, 2001). In addition, NGOs are critical for guaranteeing insurance coverage for the most marginal segment of society, which faces major constraints on self-insurance against idiosyncratic shocks.

Given the new panorama of innovative insurance options, it might be even more efficient for NGOs to concentrate on the promotion of formal risk insurance provision, rather than on ex-ante adaptation policies to diversify risks in the long term.

Cooperation between NGOs and business agents is increasingly possible and provides challenging options for complementary partnerships (Elbers, 2004; Heap, 2000). This trend might make it possible for NGOs to supply their local expertise in disaster risk insurance and to engage in more efficient long-term risk insurance arrangements.

In summary, the reduction of market failures in the disaster risk insurance market is likely to enable NGOs to shift their focus on ex-ante adaptation policies. Changes in organisational culture can further augment NGOs' ability to become engaged in the promotion of disaster risk insurance products, playing a key role in client selection and providing intermediary services to connect formal and informal insurance regimes. This will likely enhance the resilience of communities affected by earthquakes and contribute to a decrease in consumption loss after natural disasters.

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## Endnotes

- <sup>1</sup> If market failures are still in place, diversification programmes are second-best options, since market reform would be the preferred choice for directly augmenting incentives for diversification.
- <sup>2</sup> The Gini coefficient is defined as:  $G = 1/n (n+1-2(\sum_{i=1}^n (n+1-i) y_i) / \sum_{i=1}^n y_i)$  for a population of  $n$  persons indexed in non-decreasing order ( $y_i \leq y_{i+1}$ ). In the model of Ramcharan (2005), a one-point increase in the Gini coefficient leads to a USD 20.462 decrease in consumption loss as shown in Table 2, controlling for other factors.
- <sup>3</sup> Multinomial logit models are estimated with the help of maximum likelihood estimation, giving asymptotically unbiased coefficients. It is assumed the  $i_{th}$  individual chooses the alternative  $j$  for which utility  $U_j^i$  is maximal. Under this assumption, the likelihood  $p_{ij}$  of choosing a specific alternative can be modelled as  $p_{ij} = P[y_i = j] = P[\mu_{ij} + \epsilon_{ij} > \mu_{ih} + \epsilon_{ih} \text{ for all } h \neq j]$  where  $\mu_{ij} = x_i' \beta_j$  or  $\mu_{ij} = x_i' \beta$  depending on which of the two models is selected. It is assumed that individuals make independent choices so that  $\epsilon_{ij}$  and  $\epsilon_{gh}$  are independent for all  $i \neq g$  and all  $j, h = 1, \dots, m$ . The likelihood function can be written as

$$\log(L) = \sum_{i=1}^n \sum_{j=1}^m y_{ij} \log(p_{ij}) = \sum_{i=1}^n \log(p_{iy_i})$$

where  $y_{ij} = 1$  if  $y_i = j$  and  $y_{ij} = 0$  otherwise and where  $p_{ij} = p_{iy_i}$  for the actually chosen alternative  $j = y_i$ . The likelihood function consists of the sum over the  $n$  terms  $\log(p_{iy_i})$ , where  $j = y_i$  is the alternative chosen by individual  $i$  (Hey et al., 2004).

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