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Risk Zones: Comparative Lesson Drawing and Policy Learning from Flood Insurance Programs

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ABSTRACT *Risk insurance mechanisms have been proposed as proactive policy options to enhance the resilience of communities for coping with extreme events. Many risk insurance mechanisms require designation of ''risk zones'' to legalize governmental interventions. After a three-day workshop and ensuing interviews, ''wicked'' challenges were identified in the designation of risk zones: risk thresholds; land value; damage-reduction; land-use planning; forecast uncertainty; map accuracy; modifiable-areal-unit problem; winners and losers; single versus multiple hazards; and cross-jurisdictional administrative boundaries. A total of 56 peer-reviewed studies are synthesized that evaluate these ''wicked'' challenges in flood insurance programs and derive deliberative heuristics for designating risk zones in publicly sponsored insurance mechanisms.*

Introduction

To govern the risk from natural hazards in the face of complex global environmental and societal dynamics, various types of publicly sponsored risk insurance mechanisms have been proposed as proactive policy options (MacKellar et al. 1999, Amendola et al. 2000, Linnerooth-Bayer et al. 2003, Linnerooth-Bayer and Mechler 2007, 2008). Many of these risk insurance mechanisms implicitly or explicitly use the concept of ''risk zones''[1] to establish a legal basis for governmental intervention. Promoting hazard-based risk insurance schemes in designated risk zones, such as the US National Flood Insurance Program (USNFIP), can be used to mitigate, redistribute or absorb the risk from natural hazards.[2] The development and implementation of

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drought and hurricane insurance policies, and long-term land use planning for adaptation to climate change, also require the estimation and designation of risk zones (Smith and Lenhart 1996 , Adger et al. 2005, Botzen et al. 2009).

Different governments govern the risk from natural hazards differently (Glantz 2003). Some governments are more proactive, while others are more reactive. Some governments break down the hazards in different categories to deal with each separately, while others integrate the hazards in a holistic governance mechanism to deal with all types of hazards. Some governments leave it to the insurance markets to mitigate the risk, while others regulate or even subsidize the insurance markets to redistribute the risk. In some cases, governments assume the role of insurance companies. Further, regulation of development patterns and building codes also varies broadly across the spectrum of governments from local to national and international levels. The prevalence of variation in risk governance mechanisms across different governments, both horizontally and vertically, provides a rich empirical setting for comparative policy analysts to compare the effectiveness of risk governance mechanisms. The equity, efficiency and other impacts of risk governance mechanisms can also be assessed on a comparative basis.

The comparative analysis of differential risk governance mechanisms has the potential to transfer good practices, learnable lessons and effective mitigation strategies from one community to another. There is a huge potential to learn from one government's experience before applying similar risk governance policies in other socio-economic and technological contexts. This policy learning process, however, is very dynamic and context-specific and cannot be seamlessly transferred from one place to another.

To investigate various risk governance issues from the perspective of the developing countries, we organized an international workshop in Islamabad, Pakistan in 2005.[3] It was during the group discussions in this workshop as well as interviews with different stakeholders participating in this workshop that we found the issue of designating ''risk zones'' to be a salient problem for designing risk insurance policies aimed at mitigating risk from natural disasters. While findings from one workshop have limited generalizability, we were struck by many generalizable ''wicked'' challenges that were voiced by workshop participants for designating risk zones. We designate these issues as ''wicked'' because they appear to contain similar characteristics that were defined by Churchman (1967) and Rittel and Webber (1973) for ''benign'' versus ''wicked'' policy and planning problems such as there is no definitive formulation of a wicked problem; wicked problems have no stopping rule; and solutions to wicked problems are not true-or-false, but good-or-bad. Ackoff (1974) characterized these problems as ''policy messes''. There is a growing body of literature on wicked problems in public policy and public administration (e.g. see Roberts 2000, Weber and Khademian 2008). In this context, qualitative and interpretative processing of workshop and interview data led to the identification of the following ten ''wicked'' challenges that were raised for the designation of risk zones to introduce public policy interventions as part of risk governance strategies:

(1) Risk thresholds: what cut-point criteria are used to designate risk zones?
(2) Land value: what are the effects on the land value when designated as risk zones?

(3) Damage reduction: Do publicly funded or micro-insurance programs in designated risk zones reduce damages?
(4) Land-use planning: Do designated risk zones contradict or complement the current local or provincial level land-use planning and zoning practices?
(5) Forecast uncertainty: How is the forecast uncertainty incorporated in the risk premiums for national or micro-insurance programs?
(6) Costs of accurate maps: what levels of investments are needed to continuously update risk zoning maps? What are the trade-offs between accuracy and costs?
(7) Modifiable area unit problem (MAUP): How should individual or community level actuarial risk be determined in risk zones through aggregate-level data?
(8) Winners and losers: Who are the winners and losers when public or micro-insurance programs are funded in designated risk zones?
(9) Single versus multiple hazards: Are risk zones established for each hazard separately or combined with other hazards? Further, must public insurance and micro-insurance programs be oriented to mitigate single or multiple hazards?
(10) Cross-jurisdictional administrative boundaries: How should public and micro-insurance programs be designed and managed when designated risk zones cut across established administrative boundaries?

These ten ''wicked'' design challenges point to the role of broader societal dynamics and policies in differential risk exposure of communities in developing and developed countries. Comfort et al. (1999, p. 39) expressed this concisely:

> there is a widespread failure to recognize and address connections between changes in land use, settlement policies, population distributions and the accompanying degradation of habitats on the one hand and dramatically increased levels of hazard exposure and vulnerability on the other. We propose that human vulnerability – those circumstances that place people at risk while reducing their means of response or denying them available protection – becomes an integral concern in the development and evaluation of disaster policies.

While policies, such as USNFIP and experimental micro-insurance programs in countries like India, assume that risk zones can be designated through some rational or expert-based system, we argue that the designation of risk zones is also a political, social and value-laden process. Further, expert-based systems can be gamed to serve the political and normative goals of more powerful decision makers, often at the cost of vulnerable populations, for whom risk governance mechanisms apparently purport to be designed. Based on these arguments, we recommend that the designation of risk zones should be a more transparent and participatory process and vulnerable groups should be especially empowered to participate in the risk-zoning related deliberations. To facilitate these deliberations among scientists, policy makers and affected stakeholders, we undertake an in-depth analysis of these ten design challenges from the empirical perspective of flood insurance programs, such as USNFIP, and derive key deliberative heuristics that could be used by policy makers in both developed and developing countries for setting up participatory risk governance regimes.

Research Synthesis Methodology

For synthesizing evaluation literature on USNFIP and other such programs vis-à-vis challenges of designating risk zones, we searched in Google Scholar, ABI/INFORM global (proquest), Academic Onefile and Academic Search Premier to select a sample of published papers that address "flood insurance programs". After an initial review of more than 120 papers, we sampled 56 papers (marked with asterisks in the reference section). These papers were shortlisted from a larger pool based on their relevance to the study goals, i.e. whether they addressed any of the ten wicked challenges in publicly sponsored flood insurance mechanisms and, above all, whether they were peer reviewed. These 56 papers represent a broad array of disciplines ranging from economics, planning, geography, disaster management, risk management, and law to policy. These articles are drawn from following journals: *Geoforum*, *Applied Geography*, *Ecological Economics*, *Land Economics*, *Environmental Hazards*, *The Journal of Risk and Insurance*, *Global Environmental Change Part B: Environmental Hazards*, *The Annals of the American Academy of Political and Social Science*, *Environmental Politics*, *Federal Reserve Bank of St. Louis Review*, *Ocean & Coastal Management*, *Water Resources Bulletin*, *Journal of Insurance Regulation*, *Journal of Coastal Research*, *William & Mary Law Review*, *Disasters*, *OECD Journal: General Papers*, *The Journal of Real Estate Research*, *Journal of the American Planning Association*, *Journal of Agricultural and Applied Economics*, *Social Research: An International Quarterly*, *Policy Studies Journal*, *Journal of Public Economics*, *Journal of Real Estate Finance Economics*, *Planning*, *Natural Hazards*, *Journal of Housing Research*, *Climatic Change*, *Journal of Climate*, *Independent Review*, *Journal of Business Research*, *Environmental Hazards, Regulation*, *Journal of Tropical Geography*, *Risk Analysis*, *Journal of Urban Economics, Landscape and Urban Planning*, *The Social Science Journal*, *Journal of Environmental Planning & Management* and the *International Journal of Social Economics*. Since a majority of these 56 "peer reviewed" studies are focused on evaluating USNFIP, the sampled papers do not adequately represent publicly funded flood insurance programs in non-English-speaking countries (e.g. France) or privately funded flood insurance programs (e.g. England), which is a limitation of this study. Following Boruch and Petrosino's (2004) methodology of implementing research syntheses, we synthesized the findings from these 56 papers on ten wicked challenges for designating risk zones that were identified during the Islamabad workshop and interviews.

Wicked Challenges for Designating Risk Zones

Risk Thresholds

Setting risk thresholds for designating risk zones is one of the most contested scientific and socio-political problems. The flood insurance program in the US defines the Special Flood Hazard Area (SFHA) as the area of land that would be inundated by a flood having a 1 per cent chance of occurring in any given year (also referred to as the base-flood or the 100-year flood). These areas are delineated on Flood Insurance Rate Maps (FIRMs), which are generated in the US by Federal

Emergency Management Agency (FEMA).[4] Flood frequency analysis is estimated through statistical models for identification of those communities at risk of flooding.

The criterion of determining 100-year floods is an example of threshold-based decision criteria, which means that changes in thresholds will result in sensitive variation of designated flood risk zones. The 1 per cent chance flood is an arbitrary criterion and its estimate is uncertain, particularly with climatic change. Uncertainty in the estimate of the 1 per cent chance flood could mean that residents outside of the SFHA actually live in an area where flood risk is higher than a probability of 1 per cent in any year. Green and Petal (2008) consider the flood zones in the UK inadequate because of the inaccuracies in predicting flooding due in part to urbanization, climate change, and the lack of historical records. Further, neglect of coastal erosion (Kriesel and Landry 2004) or overestimation of levee strength (McKenzie and Levendis 2010) could also cause such misperceptions among the populations living outside designated flood zones. Young (2008) argues that remapping of 500-year floodplain maps could potentially extend mandatory coverage. Zahran et al. (2009) propose development of Community Rating Systems (CRS) to designate insurance premiums, with discounted premiums for those communities that demonstrate preparedness for the flood risk.

Local governments can potentially adopt more stringent criteria than those required by the USNFIP. One suggested adaptation to climatic uncertainty could be to regulate floodplains with a lower probability of flooding than 1 per cent per year, but regulation outside of the SFHA is expected to be unpopular politically due to the perceived adverse economic effects on property owners. In Netherlands, as discussed by Botzen et al. (2009), the "dike rings", governed by the "Water Embankment Act of 1996", have a safety goal of protecting against 10,000-year or 0.0001 per cent chance of flooding. Coastal Building Zones in Florida represent special criteria mandated by local communities to deal with wind, beach erosion and flooding simultaneously (Dehring 2006a, 2006b). In summary, we find that the predefined 100-year, 500-year or 10,000-year criteria cannot be seamlessly applied in different countries. Instead, more robust criteria must be established to designate flood or other risk zones.

Land Value

The designation of the risk zones has economic implications for the local community. If insurance rates were actuarially correct, the annual payment for risk insurance on a specific hazard should equal the expected annual damage from that hazard. For USNFIP, Chivers and Flores (2002) estimated that the present value of risk insurance premiums range from 2 per cent to 19 per cent of the value of the covered structure and contents. In a perfect market with perfect information, the expected present value of a hazard's damages would be capitalized into the market value of the property located in the risk zone of that hazard. A number of studies have found that this is sometimes true, but often it is not true (Chao et al. 1998).

Past empirical research has come to varying conclusions about how hazardous risk zoning and development regulations affect property values and development potential. Several studies analyzed by Montz and Gruntfest (1986), Tobin and Montz (1988) and Evatt (2000) come up with conflicting evidence as to how flood zones affect property values. On the one hand, Barnard (1978), Donnelly (1989) and

Holway and Burby (1990, 1993) argue that floodplain regulations lower property values for undeveloped floodplain land. Prices are lowered because building costs in the floodplain are higher due to regulations that require the elevation of new construction above the level of a 100-year flood. Recently, Troy and Romm (2004) found that the insurance has an effect in decreasing the land value because premiums and the cost of flood insurance are calculated negatively in purchase prices and price differences also include those non-insurable costs. Similarly, Harrison et al. (2001), Dehring (2006a) and Bin et al. (2008) found a similar effect: the flood insurance program decreased property values.

Other studies have found that flood hazards have no effect on land values. Two early studies that specifically examined the effects of floodplain regulations, as well as flood hazards, on land values have concluded that the regulations have no effect on the value of developed property in floodplains (Damianos and Shabman 1976, Muckleston 1983). Recently, Morgan (2007) found that subsidized flood insurance helps prop up demand and housing prices in floodplain areas are higher than in non-floodplain areas. In general, all natural hazard insurance schemes have an element, more or less large, of cross-subsidy (e.g. people on the flat are subsidizing landslide damage insurance for people on slopes; and people on slopes are subsidizing flood insurance for people on the flat).

Pompe and Rinehart (2008a) argue that the USNFIP provides subsidies to some homeowners in flood prone areas. Without such insurance subsidies, it would be too expensive for many people who already live there to continue to live there. Demand for subsidized homes is higher than it would be in the absence of such subsidies. Power and Shows (1979) made a similar argument that the USNFIP increases the demand for land that will eventually receive subsidized flood insurance premiums, once the floodplain management maps are completed for that land. Shilling et al. (1989) proposed that the USNFIP increases the land value for those homeowners with subsidized premiums. Any new home construction after floodplain management plans are implemented is subjected to actuarial rates instead of the subsidized rates imposed on already existing homes. Hedonic regression techniques demonstrated that subsidized homeowners pay 4 per cent less than homeowners with actuarial rates, resulting in a $4 billion wealth transfer nationwide. Zahran et al. (2009) argued that insured areas are enticing to homeowners because of the amenities they offer and they are deterred by the hazard of a flood ''only to the extent that they perceive a significant flood risk''. Similarly, Helvarg (2005) criticizes the sense of security that flood insurance creates that allows mortgages for high risk properties in flood zones. Bagstad et al. (2007) contend that flood prone areas that are undeveloped sell at lower costs, but once developed the value is increased. Shrubsole and Scherer (1996) focused on flood policies in Canada and found no conclusive evidence for how land value was affected by floodplain regulations.

The empirical studies, in general, suffer from several key weaknesses, which probably explain the divergent conclusions. First, the studies explicitly controlled for only a few of the factors affecting land value. Second, the expected effects of flood hazard and floodplain regulations on the development potential of land and construction cost should be capitalized into the value of vacant land. Many of these studies examined developed residential properties, not vacant land.

Extending the analogy from floods to other natural hazards, neither the previous research efforts on USNFIP evaluation nor empirical studies for other hazardous program evaluation have specifically examined the cumulative and differentiated effects of multiple hazards on the land values and the likelihood of development, controlling for all other potential effects. We recommend that this kind of research be assigned priority at the international scale to inform risk insurance-based policy designs and to facilitate the context-sensitive designation of risk zones.

Damage Reduction

It is not certain whether risk zoning-based building regulations have reduced damage. For the example of USNFIP, Holway and Burby (1993) provide evidence that USNFIP-mandated building regulations have reduced losses and development in riverine flood hazard areas. Helvarg (2005) suggests that flood insurance slightly decreases flood damage by establishing some minimal standards, which are otherwise considered inadequate in the case of coastal flooding. Luechinger and Raschky (2009) argue that government-mandated insurance appears to compensate for any loss sustained in the housing market price of the property. Botzen et al. (2009) propose that flood insurance (not specifically mandated) would be effective at reducing flood damage because survey results show that property owners would respond to incentives to improve flood mitigation construction in exchange for reduced premiums or increased coverage.

On the other hand, Montz and Gruntfest (1986), Shilling et al. (1989), Bagstad et al. (2007) and Pompe and Rinehart (2008a, 2008b) argue that the USNFIP does not reduce flood damage because it increases demand for homes in flood prone areas, where premiums collected are insufficient to compensate for damage payments. Furthermore, Richman (1993) posited that reductions in infrastructure costs as well as affordable insurance premiums through the USNFIP cause more people to move to flood prone areas, which creates more vulnerability to damage, especially when people do not improve the structure of their homes because the government continues to offer insurance and disaster relief even when homes are damaged. Carolan (2007) argues that the program is inefficient because flood damage is occurring in areas outside the 100-year flood zones. Raschky and Weck-Hannemann (2007) argue that USNFIP does not reduce damage because fewer people opt to get insurance against flooding under the expectation that the government will provide financial aid to those who are uninsured or underinsured in the event of a catastrophe. Sarewitz et al. (2003) argue that vulnerability reduction policies do not only consider the risk probabilities of events but also focus on how best to reduce potential damage regardless of risk. Understanding the risk alone will not make structures in flood zones less vulnerable, if they are not altered to sustain the floods. The USNFIP needs to utilize both concepts to help move construction out of areas with high risks of flooding and to encourage better building codes to reduce vulnerability. In summary, past empirical research shows conflicting evidence whether risk zoning-based building regulations increase or decrease damage. We recommend that if risk zones do not reduce damage, an investigation must be carried out to identify the causes and proper modifications must be made in government policies and strategies to stimulate the development of more resilient buildings.

Land-Use Planning

The majority of the workshop participants and expert interviewees agreed that if the communities wish to further reduce the rate of increase in the occupancy of hazardous risk zones, they must supplement the building construction requirements (such as building elevation requirements proposed in the USNFIP) with land-use regulations limiting new development. The federal governments (and, for that matter, local governments as well) have however neglected to use local land-use controls to keep people and buildings away from hazards and, thus, hold down hazard damages.

Traditional land-use policies are focused on providing infrastructure and meeting sewer and water needs without explicitly treating hazard mitigation in land-use zoning (Tobin 1999). In contrast, Blanchard-Boehm et al. (2001) argue that flood mitigation and flood risk reduction have been primary drivers of land-use planning. Recent trends in the neo-urbanist movement suggest that smart growth and integrated development plans, which are primarily aimed at growth management and urban sprawl reduction, explicitly consider hazard mitigation aspects in designing resilient communities (Stevens et al. 2010).

The broader land-use controls have been planned in South Asian countries but they have not been systematically implemented due to a host of political, economic and development problems. Even if some local, provincial or state governments have required risk zones to be left alone (i.e. no human settlements), landless farming communities and urban poor migrate to those risky areas and establish so-called illegal land developments (Hameed 2005). Local and state governments in South Asia do not have enough resources to stop these land-use developments, even if laws or regulations exist on paper. Implementation failures of such land-use policy regulations in developing countries are complicated by the problem of corruption (Zia 1999).

In summary, land-use plans are neither implemented as planned nor do they typically include hazard mitigation planning as explicit criteria for designing land-use zoning regulations. We support the broader use of land-use planning for long-term mitigation and regulation of hazards. Adaptive policy mechanisms that respond to ground realities and forecast uncertainties could facilitate such changes in land-use planning.

Forecast Uncertainty

The USNFIP provides an interesting example of policy implementation for managing flood risk by using flood frequency estimates to designate flood risk zones. Olsen and Olsen (2006) argue that the assumption behind traditional flood risk analysis is that climate is stationary, but anthropogenic climate change and better knowledge of inter-decadal climate variability challenge the validity of the assumption. Olsen and Olsen (2006) review several alternative statistical models for flood risk estimation that do not assume stationary climate. Although currently out of favor, Olsen and Olsen (2006) argue, hydro-meteorological models have been used for engineering design as alternatives to statistical models and could be adapted to different climate conditions. Hydro-meteorological models are thus proposed as scientific and objective ways to designate risk zones in flood prone areas.

Pielke Jr. and Downton (2000) correlated US flood damage data (1932–1997) with the precipitation data and found that precipitation measures significantly explain variation in flood damage. The growth in recent decades in total damage is related to both societal factors and climate factors. These findings suggest that climatic changes causing precipitation variability shifts will more likely increase societal damage outside the risk zones established through data from the past 100 years unless anticipatory adaptations through appropriate policy mechanisms are introduced.

Another problem with risk zoning is that climate variability causes uncertainty in the hazard's frequency estimates, such as flood frequency estimates used by USNFIP regulators. Greater uncertainty in actuarial rates could cause a private insurance company to restrict coverage or raise premiums to account for potentially greater risk. However, local or national governments are different from private insurance companies. Raising rates by governmental agencies, such as the US proposals to improve the USNFIP's financial health, could have an adverse effect on other federal disaster relief costs, such as Small Business Administration loans or FEMA disaster assistance grants (GAO 2001) and cause some policyholders to cancel their coverage.

Higher premiums thus do not seem to be a viable option to account for the additional uncertainty in hazardous risk estimates resulting from climate variability. This implies that climate change risk in the risk insurance programs will have to be borne by taxpayers. In many societies, taxpayers are already burdened with over-taxed fiscal policies, and adding hazardous taxes will be opposed for political reasons. We argue that there is no single best method to redistribute the risk caused by forecast uncertainty. Rather, iterative deliberative mechanisms must be institutionalized to decide who (governments, insurance industry or citizens) will bear the increased risk premiums necessitated by internalizing forecast uncertainty.

Costs of Accurate Maps

Meenar et al. (2006) present the problem of ''accurate'' zoning in the context of disaster management and land-use planning issues. They argue (2006: 31) that, to manage flooding and flood insurance policies, communities must be able to measure floodplains correctly. About 20,000 communities have used FEMA floodplain maps for the past 30 years. But many existing maps are out of date by decades and do not reflect today's actual floodplain boundaries. Up-to-date maps are needed to ensure that flood insurance programs are more closely aligned with actuarial risk, encourage wise floodplain management, and increase the public's flood hazard awareness.

Earlier, Power and Shows (1979) found that many reports have been received from communities that the maps are inaccurate and take too long to create. However, no claims have won in court. Arnell (1984) discusses two methods: a ''detailed'' method that is more accurate but costlier, and an ''approximate'' method that is less accurate but also less costly. Parker (1995) suggests that local governing authorities rely on floodplain maps which are often inaccurate and unreliable. They have difficulty in restricting the development of floodplains. Burby (2001) notes that the flood zones specifically exclude areas that experience problems due to ineffective storm drainage. Omitting areas that experience flooding regularly maps the zone inaccurately. Carolan (2007) finds that the floodplain maps do not always take into account the

changes caused by new development, causing maps to be inaccurate. This is complicated by the fact that ~60% of maps are at least ten years old.

Many developing countries cannot afford high-resolution satellite maps, like the ones used in the US, for floodplain management. As a cheaper substitute, Sanyal and Lu (2006) created a hazard index on a map of lower resolution. Variables such as flood frequency, population density, transportation networks, access to potable water and availability of higher ground were mapped in this hazard index map. Overall, generation of accurate risk zone maps is not a one-shot task. Rather, due to the dynamic nature of socio-ecological systems, even 100-year floodplain maps need to be dynamically updated, which raises the costs of these programs. These costs are prohibitively high for developing countries, but worthy of international development investment for long-term capacity building in the developing countries.

Modifiable Area Unit Problem (MAUP)

The Modifiable Area Unit Problem (MAUP) has been recognized as a major problem in risk management and policy science literature that also affects the estimation methods of risk zones. Risk assessment models normally require the integration of pixel-based environmental hazard data with area-based socio-economic data, which poses problems of MAUP, also known as ecological fallacy (Openshaw 1984). MAUP arises due to the scale effect and zoning effect when areal units are aggregated to form units of different spatial arrangements. Fotheringham and Wong (1991) provided strong empirical evidence on the unreliability of multivariate analysis undertaken with areal socio-economic data at different zone levels or spatial scales. Similarly, the estimation of societal vulnerability from hazardous risk will require the integration of socio-economic data with hazardous risk data. The choice of scale by policy implementation agencies will affect the determination of risk zone boundaries, which can pose inconsistency problems for rank-ordering risk zones based on their societal vulnerability and/or determining appropriate insurance premiums based on societal income groups.

One of the possible solutions to deal with MAUP is to gather data at very fine resolution or at highly disaggregated scale (Chen et al. 2003), but this is a very costly proposal for developing countries. Solutions have also been offered to analyze data at multiple scales, such as hierarchical models (Hansen and Bausch 2005), or cross-scalar models (Adger et al. 2005). Most of these possible solutions of MAUP require gathering individual/household level socio-economic data, which is often difficult due to privacy and cost-related issues. In summary, we contend that MAUP makes it impossible to determine risk zones based on any single best technical solution. Risk and disaster management experts must recognize this limitation.

Winners and Losers

The choice of different zoning criteria results in the determination of risk zones that can potentially benefit some stakeholders and harm others. Participants in the Islamabad workshop presented strong arguments about winner–loser effects of risk zones. Policy decisions about the criteria of risk zones, as well as land-use zones, directly affect the distribution of wealth. Since there is no single best technical

method (as shown in the MAUP problem above), the choices on risk-zoning criteria are social and political in nature. There are contested arguments in the literature about who wins and who loses by establishing USNFIP type of programs.

Power and Shows (1979, 1981), Shilling et al. (1989), Daniel (2001), Pompe and Rinehart (2008a, 2008b), Klein and Wang (2009) and Levy (2007) argue that the winners are the people receiving government subsidized premiums to live in known highly flood prone areas, while taxpayers are losers. According to the charity hazard theory (Raschky and Weck-Hannemann 2007), the winners are the uninsured and underinsured who pay no flood insurance premiums, but receive financial aid in the event of a flood. The losers are the taxpayers who bear this financial burden and the flood insurance policy holders who pay higher premiums than they would if these uninsured were in the pool.

Holway and Burby (1990, 1993) argue that the municipalities seem to be losers in that land values in floodplains are decreased and in turn the tax base is reduced. Harrison et al. (2001) argued that winners are municipalities which appear to be over-valuing properties in SFHA and, therefore, are collecting more taxes than is reasonable. Griffith (1994), Burby (2006) and Carolan (2007) suggest that local governments are winners so long as the federal government assumes the majority of the cost in building enforcement, flood mitigation and damage payments.

In the case of India, Mohapatra and Singh (2003) argued that flood insurance is only popular in the urban areas, so residents in the urban areas benefit substantially from the insurance coverage while rural populations lose in the long run. Olsen and Olsen (2006) argued that the taxpayers will absorb any risk due to climate change uncertainty, so in the long run, winners are the flood insurance customers while the taxpayers are the losers. Gopalakrishnan and Okada (2007) argue that the society as a whole is a loser due to systematic failures in disaster management. In particular, losers are those people who are poor and live in low-lying areas throughout the world. Cummins (2006) suggests that government mandated risk insurance programs such as USNFIP lock out insurance companies from the market; hence insurance companies are the losers. Chivers and Flores (2002) argue that home buyers in flood zones are losers as they typically do not know about USNFIP requirements until closing and are unable to factor USNFIP requirements into the offer. Similarly, Evatt (2000) suggests that developers and local governments with increased property tax base are winners of public insurance schemes. Bell and Tobin (2007) suggest that winners are those who respond positively to the flood risk information being conveyed and the losers are those who do not respond to flood insurance risk information. In summary, whether government-subsidized or micro-insurance programs, each method or criterion to determine risk zones results in a different distribution of winners and losers. Redistributional consequences of risk governance mechanisms must be made transparent, while acknowledging that such information is contested.

Single Versus Multiple Hazards

Another major challenge identified with risk zoning is the issue of overlapping risk zones in the case of multiple natural hazards in a given area. Many workshop participants and interviewees argued that instead of developing single-hazard risk

zones, it would be more appropriate to develop multi-hazard risk zones. However, multi-hazard risk zones lead to the problem of integrating damage from multiple hazards over heterogeneous time-scales for determining actuarial rates. For example, flood insurance in Spain and France falls under a catastrophe coverage program required for all property owners. The French and Spanish model has been criticized for inducing moral hazards through its lack of incentives in stimulating robust building designs (Linnerooth-Bayer et al. 2003, Klein and Wang 2009).

Friedman et al. (2002) and Keeler et al. (2003) propose that the erosion insurance could be combined with the flood insurance. Another insurance program that is offered with flood insurance is wind damage through private insurers (Kunreuther 2008). In India, private insurance companies are combining flood insurance with other risks (Mohapatra and Singh 2003). Arnell et al. (1984) report that flood insurance is generally a part of regular insurance policies in Britain along with storm, fire and theft insurance. Pompe and Rinehart (2008b) report that some southern states like Florida offer state-subsidized hail and wind damage insurance because the USNFIP does not. In summary, we argue that the establishment of multi-hazard zones is desirable from a policy standpoint over single-hazard risk zones. While the French and Spanish model has incentive and moral hazard problems, design of multiple-hazard risk zones could be manipulated to minimize moral hazards.

Cross-jurisdictional Administrative Boundaries

Blanchard-Boehm et al. (2001: 26) note that flood insurance zones spill over traditional boundaries including historical water rights governed by ''prior appropriation doctrine''. Burby (2001) suggests that zones do spill over, though the US program allows for local municipalities to go above and beyond the USNFIP requirements. Bagstad et al. (2007) note that historically, in the US, the Army Corp of Engineers (USACE) has managed coastal and other major waterways that cross assorted boundaries. Currently, USACE is in the process of transferring control to local municipalities. Carolan (2007) sums up the cross-boundary problem in terms of enforcement issues. Though the flood zones and the regulations surrounding them are created by the federal government, enforcement is left to local governments and often not enforced. Many workshop participants and interviewees recommended that inter-organizational governance networks for risk zoning should be established and periodically revisited. Both expert and citizen groups should be represented in these inter-organizational governance networks, and governmental and non-governmental agencies should be given adequate representation. The problems of assigning accountability in these inter-organizational governance networks remain unresolved (Koliba et al. 2010) and need to be studied further in the context of enforcing programmatic regulations.

Conclusions

Risk insurance mechanisms have been proposed as proactive policy options to enhance the resilience of communities for coping with extreme events. The risk insurance mechanisms, such as government subsidized public insurance programs or micro-insurance programs, typically require designation of ''risk zones'' to establish

a legal basis for governmental intervention. A three-day workshop on the societal impacts of weather and climate affairs led to the identification of ten "wicked" design challenges to designate risk zones for such proactive policy interventions. Using workshop and interview data, and synthesis of peer reviewed literature on flood insurance programs, we argue for a broad shift from expert-based technological systems to multiple stakeholder-based deliberative approaches for designating risk zones. In particular, we recommend following deliberative heuristics for the design and implementation of risk insurance mechanisms that require designation of risk zones in different governance systems:

(1) Risk thresholds, such as a 1% criterion for differentiating flood risk zones, must not be arbitrarily selected. The predefined 100-year, 500-year or 10,000-year criteria cannot be seamlessly applied in different countries. Instead, more robust criteria must be established to designate flood or other risk zones.
(2) There is no consensus as to whether risk zoning increases or decreases the land value of risk zones. More context-specific and rigorous studies are needed.
(3) When risk zones do not reduce damages from intended risks, an investigation must be carried out to identify the causes and proper modifications must be made in government policies and strategies to stimulate the development of more resilient buildings.
(4) When land-use zones are not implemented as planned, or in some cases no land-use planning is undertaken, adaptive policy mechanisms are needed.
(5) Iterative deliberative mechanisms are needed to decide who (i.e. governments, insurance industry, citizens) will bear the increased risk premiums necessitated by scientific uncertainty, such as when climatic forecast uncertainty spills over initially designated flood or drought zones.
(6) Existing risk zone maps are inaccurate partially because risk zones are dynamically changing as a result of land-use changes and geological shifts. More resources are needed to keep risk zone maps accurate over time.
(7) Modifiable Area Unit Problem (MAUP) makes it impossible to determine risk zones based on any single best technical solution. Risk management experts must recognize this limitation.
(8) Each method or criterion to determine risk zones results in a different distribution of winners and losers. Redistributional consequences of risk governance mechanisms must be made transparent, while acknowledging that such information is contested.
(9) Establishment of multi-hazard risk zones is desirable from a policy standpoint over single-hazard risk zones, and the design of multiple-hazard risk zones could be manipulated to minimize moral hazards.
(10) Designation of risk zones spills over traditional administrative boundaries. Inter-organizational governance networks must be strengthened to periodically update risk zones.

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Notes

1. Broadly, a risk zone may be defined as a three-dimensional spatial frame that is exposed to an exogenous or endogenous hazard over time. Zandvoort (2008) discusses risk zoning and risk mapping as possible instruments for informing the public about the siting of nuclear power plants. With the advent of GIS and remote sensing data integration technologies, risk zoning based hazard mitigation methods have been proposed for earthquakes, fires, landslides, volcanoes, floods, coastal inundation and other hazards (Fangqiang et al. 2003, Sharma et al. 2003, Tralli et al. 2005, Zhang and Huang 2005, Kirchsteiger 2006, Alzbutas and Maioli 2008, Fell et al. 2008; Zandvoort 2008).
2. We assume that the higher the capacity of a community to absorb risk from natural hazards, the more resilient is that community.
3. A three-day workshop on "societal impacts of weather and climate affairs" was organized in Islamabad, Pakistan on November 24–26, 2005. Twenty-six experts from Pakistan, India, Nepal, Bangladesh, the US and Norway participated in this international workshop. The proceedings of the workshop were videotaped for interpretive and discourse analysis. A key objective of this workshop was to identify the institutional arrangements that are needed in South Asia to proactively plan for natural disasters and persuasively carry out relief and recovery operations.
4. More information is available at http://www.fema.gov/hazard/map/firm.shtm

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