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Determining Public Policy and Resource Allocation Priorities for Mitigating Natural Hazards: A Capabilities-based Approach

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Abstract This paper proposes a Capabilities-based Approach to guide hazard mitigation efforts. First, a discussion is provided of the criteria that should be met by an adequate framework for formulating public policy and allocating resources. This paper shows why a common decision-aiding tool, Cost-benefit Analysis, fails to fulfill such criteria. A Capabilities-based Approach to hazard mitigation is then presented, drawing on the framework originally developed in the context of development economics and policy. The focus of a Capabilities-based Approach is protecting and promoting the well-being of individuals. Capabilities are dimensions of well-being and specified in terms of functionings. Functionings capture the various things of value an individual does or becomes in his or her life, including being alive, being healthy, and being sheltered. Capabilities refer to the real achievability of specific functionings. In the context of hazard mitigation, from a Capabilities-based Approach, decision- and policy-makers should consider the acceptability and tolerability of risks along with the affectability of hazards when determining policy formulation and resource allocation. Finally, the paper shows how the proposed approach satisfies the required criteria, and overcomes the limitations of Cost-benefit Analysis, while maintaining its strengths.

Keywords Capabilities · Capabilities-based Approach · Natural Hazards · Mitigation

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Introduction

Public policy formulation and resource allocation strategies at the federal, state, and local levels currently address, and can help in mitigating the risks posed by, natural hazards. Natural hazards are herein defined as potentially damaging or destructive natural events (e.g., tornados, hurricanes, earthquakes).[1] The federal government sets aside money for risk reduction, establishes conditions for disaster aid, and regulates activity in the public and private sectors by setting standards for acceptable business conduct (e.g., constraints on how insurance agencies conduct business). State policies mandate building code enforcement and establish regulations on construction. Local policies specify restrictions on land use and pass zoning ordinances. These public policies are designed to help reduce the impact of natural hazards.

While the strategies used by different government agencies vary, they all share the same overarching aim: safeguarding the public from, and minimizing the societal impacts due to, hazards. This aim is reflected in the three major objectives of public policies and resource allocation strategies that deal with natural hazards: (1) protecting individuals and communities from hazards by, for example, reducing the losses that might result from hazards, (2) informing and warning individuals and communities vulnerable to hazards, and (3) increasing our understanding of hazards and the efficacy of mitigation measures [1, p. 60].

In practice, societies often face multiple hazards, each of which might require different mitigation strategies, and the allocated resources for risk mitigation are limited. Thus, there is a need for a framework for (1) prioritizing the hazards to address, (2) evaluating potential strategies for dealing with them (e.g., to see whether they effectively address the overarching aim of risk mitigation strategies), and (3) choosing the most appropriate strategies.

This paper develops such a framework to help policy- and decision-makers address the overarching goal of risk mitigation. Our proposed Capabilities-based Approach to public policy and resource allocation provides criteria in terms of which we should evaluate available risk mitigation strategies and thus can guide decision-makers. Our Capabilities-based Approach is an alternative to Cost-benefit Analysis. Cost-benefit Analysis is commonly used as a tool for policy- and decision-makers. This kind of analysis has two primary benefits: it aims to achieve an efficient allocation of resources and it is relatively simple for decision-makers, who are typically non-technical experts, to use. However, it also has several limitations, which we discuss in this paper. In particular, it does not account for all of the moral factors that should influence policy formation including the distribution of risks. The proposed Capabilities-based Approach maintains the strengths of Cost-benefit Analysis while avoiding its limitations.

[1] This is evidenced by the following statistic. "In the 1970s, natural disasters alone claimed nearly 2 million lives. By the 1990s, even though the occurrence of disasters was greater, fatalities had fallen to under 800,000. This shows that it is possible to reduce the loss of life, although the total number of people affected by disasters did increase markedly." (Paper prepared by FAO for the second international conference on early warning).

This paper has five sections. The first discusses why information from risk analysis is important in developing and implementing mitigation strategies with respect to natural hazards and the additional inputs a decision-aiding framework must consider. The second considers the criteria for evaluating specific decision-aiding approaches. The third critically assesses Cost-benefit Analysis. The fourth describes our proposed Capabilities-based Approach to decision-making. The fifth and final section shows how our proposed approach fulfills the criteria discussed in the second section.

Public Policy, Resource Allocation, and the Mitigation of Natural Hazards

Risk analysis provides necessary inputs for rational decision-making for public policy and resource allocation. In this section we discuss why the information provided by risk analysis is essential. Additional inputs, like further value judgments and information about available mitigation strategies, as well as a rational framework to combine these inputs, are also required. The second half of this section elaborates on how the information from risk analysis and the additional inputs should be combined into a rational framework for decision-making.

Risk Analysis: A Tool for Public Policy and Resource Allocation

Every decision-making process in the context of hazard mitigation must deal with uncertainties. For example, the time of occurrence of a hazard and its magnitude are uncertain. Other uncertain events, more directly influenced by our actions, include the impact of a hazard on society and the outcomes (benefits and drawbacks) of risk mitigation strategies. These uncertainties are the subject of risk analysis.

Risk generally is defined as a set of scenarios, their associated probability of occurrence, and consequences [2]. Risk analysis (or risk assessment) is typically divided into *risk determination*, which assesses the probabilities of the potential consequences, and *risk evaluation* (or management), which evaluates and makes decisions on the basis of that information [3; 4, p. 6; 5, pp. 11–12].

The information provided by risk analysis is important for public policy formulation and resource allocation strategies. Risk analysis can enable us to have a realistic understanding of the risks involved in or how risks are affected by mitigation strategies. This kind of analysis puts risk-related strategies into perspective, which in turn can help policy makers think through the impact of their decisions. Thus, the information from risk analysis contributes to the making of well-informed and responsible policy priorities and decisions [6, pp. 53–64; 7].

Policy- and decision-makers are not generally experts in risk analysis. As Irwin et al. write, “many local authorities simply do not have the necessary technical expertise to analyze the risks involved in proposed developments” [8]. Therefore, it is essential that the information from risk analysis be understandable to non-technical experts. Only in this way will policy formulation and resource allocation strategies account properly for this information in practice.

Prioritization of Public Policy and Resource Allocation Strategies

Given the limited resources available to national, state, and local governments and agencies, policy- and decision-makers require a method for prioritizing the risks faced by society and selecting the most appropriate mitigation strategy. It is important to understand which factors should influence these decisions, or the basis on which priority should be given to a specific hazard or mitigation strategy. A decision-aiding approach provides a framework for understanding how to evaluate and respond to the information provided by risk analysis and how to combine such inputs with additional considerations regarding, for example, the fairness and moral justifiability of a mitigation strategy.

Any decision-aiding approach, which specifies criteria for prioritization, will be based on and reflect specific value judgments. For example, many argue that proper allocation of resources should be concerned with avoiding the most likely hazards with greatest expected impacts before allocating resources for less likely and less detrimental hazards. Which hazards are prioritized depends on which losses are considered most significant. If loss of life is the primary criterion for impacts, "then the exposure of greatest year[-]to[-]year importance are tornadoes, riverine, and coastal flooding. If, however, the greatest value is to be placed on the phenomena that involve the largest life loss in a single event, regardless of frequency, then priority would have to be given to major earthquakes, tsunamis, and hurricane wind/storm surge occurrences." [1, p. 382]. If the criterion is economic losses, then emphasis should be placed on wind hazards, flooding, and earthquakes [1, p. 382; P. Gardoni et al. (Submitted)][2].

In this paper we develop a new approach for establishing policy priorities. Before describing the proposed approach, we discuss in the next section the criteria that need to be met for an approach to establishing priorities to be successful. After this discussion, we consider Cost-benefit Analysis, a common tool used to prioritize policies, and outline its limitations. We then go on to introduce the proposed Capabilities-based Approach as a decision-aiding approach and show how it addresses the required criteria and it avoids the limitations of currently available approaches.

Criteria for Evaluating Public Policy-aiding Approaches

Evaluative criteria for assessing available policy-aiding approaches must be based on an understanding of the function or purpose of a policy-aiding approach. In the current context, this function is to help policy- and decision-makers determine which mitigation policy for a given natural hazard should be pursued, if any. A policy-aiding approach is generally viewed as providing important information for decision-makers and policy-makers to consider in the course of the policy decision-making process. The criteria listed below are designed to ensure that the information provided by a policy-aiding approach is useful and relevant for policy-makers [9, p. 190].

[2] Gardoni, P., Murphy, C., & Sanchez-Silva, M., (2006). The practical implementation of a capabilities-based approach to measuring the societal impacts of natural and man-made hazards. *Risk Analysis* (Submitted).

There are two sets of criteria that any approach to public policy formulation and resource allocation should fulfill: *internal* and *external*. Internal criteria assess the quality of the analysis that an approach will provide in theory. External criteria capture the characteristics of the environment within which the policy-making process occurs that public policy should take into account [9, p. 190]. In this section we discuss both sets of criteria. These criteria are drawn from discussions by MacLean [10, pp. 88–92] and Merkhoffer [9, pp. 187–198].

Internal criteria are designed to ensure the quality of an analysis provided by an approach. There are three internal criteria: soundness and consistency, completeness, and accuracy.

1. Soundness and Consistency

An approach is sound and consistent if three conditions hold. First, particular judgments or decisions that an approach recommends must be theoretically defensible, or argued for on the basis of the decision-aiding framework. Second, an approach can be consistently applied in practice. Actual applications do not contradict or violate the assumptions of that theory. Third, application of a particular decision-making approach must be reliable, "in the sense that independent applications to the same problem would produce the same results" [9, p. 190]. For example, when considering mitigation strategies for hurricanes, an analysis conducted in Florida and in South Carolina should reach consistent conclusions, while accounting for regional differences.

2. Completeness

An approach is complete if it addresses all the relevant facts of a decision-making problem [9, p. 190]. In the current context, an approach must address the uncertainties associated with natural hazards and the expected societal impact of mitigation strategies. Approaches must consider not only the costs of various policies towards risk, but also the benefits that each decision may produce [10, p. 75].

3. Accuracy

An approach is accurate if it has the required precision in gauging the quantity in which we are interested, it is unbiased, and properly accounts for the underlying uncertainties inherent in the problem. An approach is not accurate when it measures, precisely or not, something different from that which we are interested in assessing.

External criteria refer to outside considerations or values that should also be considered by a decision-aiding approach. There are two main external criteria to consider: practicality and acceptability.

4. Practicality

A decision-aiding approach must be practically implementable, given available, though limited, resources and information. An appropriate amount of time and

resources must be required to reach a decision; what is appropriate will differ depending on the kind of decision-making environment and urgency.

5. Acceptability
A decision-aiding approach must be acceptable, in the sense that it is consistent with and reflects the values and priorities of the public and political institutions within a society [10, pp. 88–92; 11]. Potential values to consider include fairness; distributional equity, or who is affected by a hazard and how; and the basic principles of democratic decision-making. One of the basic principles of a democracy is that policies and laws be adopted on the basis of consent [10, p. 21]. For policies to be adopted on the basis of consent, or for a decision-making approach to be consented to, the approach must be clear and understandable, and ensure that the underlying value judgments are transparent.
In addition to respecting core values, an approach must account for the symbolic and expressive significance of public policy and decision-making agencies. That is, an approach must acknowledge and take into account the public expectation that policies made by public agencies will reflect core societal values and commitments [10, p. 92]. For example, in the American context, MacLean argues, cost-consciousness is viewed as one important, but not the only important, value. MacLean argues that the public also wants to know that important resources are being protected by the decision.

A Currently Available Tool: Cost-benefit Analysis

In this section, we discuss one of the standard tools for aiding public policy and resource allocation decision-making: Cost-benefit Analysis. We focus on this approach because it is widely used. After highlighting the strengths of Cost-benefit Analysis, we discuss its general limitations, by considering the extent to which it fulfills the criteria outlined in the previous section.

Cost-benefit Analysis offers a pragmatic way of determining which policy or allocation of recourses will lead to the most efficient use of resources. Cost-benefit Analysis is a tool used to convey information about the overall effects of policy alternatives, based on an aggregation of disparate positive and negative outcomes of each policy [12]. Characteristically the expected consequences, positive or negative, are measured in the same unit of measurement, the most common of which is monetary [13–15]. There are many versions of Cost-benefit Analysis, which differ in the consequences considered, the method used to measure them, and how the information produced by a Cost-benefit Analysis is viewed (e.g., whether it generates a presumption to act upon, provides one source of information for policy makers to consider, or supplies a strict decision rule regulators are bound to follow) [12, 16].

In many versions of Cost-benefit Analysis, preferences are taken as fixed or given and reflect how we order or rank states of affairs, in practice or as a matter of fact.

An individual prefers X to Y if she would choose X over Y. Another common assumption is that as preferences are satisfied welfare increases [16; 17, p. 12]. Often the measurement of risk is based on the subjective preferences of individuals [16; 17, p. 18]. More specifically, risks are quantified based on the amount of money individuals are willing to pay to avoid or the amount of compensation that individuals would demand for being exposed to risks. This is the willingness to pay criterion. It is common to use market behavior to determine this information. When there is no available market data, valuation surveys may be used, which ask individuals how much they would be willing to pay to avoid certain risks.

There are two primary strengths of the Cost-benefit Analysis. The first stems from its putative practicality. Cost-benefit Analysis provides a simple and straightforward way to decide which policy should be adopted or where resources should be allocated. Thus, it is unsurprising that Cost-benefit Analysis is currently used by many decision-makers. The second stems from its overarching aim: the efficient allocation of resources. Cost-benefit Analysis purports to provide a framework whereby the comparable consequences of alternative courses of action can be determined and a choice based on the most efficient allocation of resources made. Aspiring for efficiency is often viewed as important because it ensures that public resources are not squandered and a greater number of needs can be addressed with limited resources.

Despite its strengths, however, there are a number of limitations with Cost-benefit Analysis. Specifically, it is unclear whether it fulfills the criteria for decision-aiding approaches. Consider the criteria of soundness and consistency as well as accuracy. Relying on the market to determine individuals' preferences assumes that individuals are fully knowledgeable of the relative risks involved when determining what level of income they would be willing to trade to avoid exposure to given risks and that they have real options from which to choose, so that they could choose, for example, to avoid exposure to risks [18]. Often these assumptions are not justified in practice. Willingness to pay is influenced by or dependent on ability to pay. Living in conditions of poverty ensures that your willingness to pay to avoid certain risks is necessarily low. However, it should not be inferred that you either do not value, desire or should not have protection against a certain risk [16]. Consequently, it is unclear if market prices reflect people's preferences. A more general problem with relying on preferences is that people may erroneously want things that do not promote their welfare and fail to want or prefer what in fact promotes their welfare. Individuals adapt to limiting circumstances. So people might show a low willingness-to-pay for environmental goods because they have adjusted to bad environmental or health levels [16]. The phenomena of adaptive preferences calls into question the assumption that market behavior is a good measure of the societal impact of a given hazard, as measured by its impact on the well-being of individuals [9, p. 193].

The completeness of Cost-benefit Analysis is also questionable, especially in contexts where the impact of a policy is not easily translated into economic terms or does not have strictly economic implications. For example, the impact of Hurricane Katrina, that hit New Orleans and the State of Louisiana in August 2005, went beyond the economic losses calculated in terms of the buildings destroyed to

include, for example, the loss of historical districts and landmarks and the re-shaping of an entire city. Furthermore, it is questionable whether the value or merit of a policy is reducible to its economic or monetary impact [12]. Nor is it clear that morally relevant consequences, including the impact of policies on moral rights can be accounted for, especially in the appropriate way. The impact of a policy on rights, many argue, should not be treated as one of many consequences a policy may have that should be included in the aggregation of the net effects. Rather, respect for rights sets boundaries on permissible policies to pursue [12].

Finally, there are questions surrounding the acceptability of Cost-benefit Analysis. Despite its putative practicality and widespread use among decision-makers, the monetary unit of measurement raises moral problems. Critics have argued that it is offensive and immoral to assign a monetary value to a consequence like the loss of a human life, as well as difficult to determine non-arbitrarily [13–15, 18]. In addition, Cost-benefit Analysis does not take into consideration the distributional impact of policies, for example, the distribution of risks and benefits [19, p. 165; 20], yet fairness is an important societal value that decision-aiding approaches should take into account [10, pp. 78–85; 21, pp. 49–71].

In addition, many argue that democracy entails a commitment to making certain policy decisions on the basis of the considered ethical judgments of citizens, not simply on the basis of aggregating individuals' willingness to pay [16, 18]. Certain policies present moral questions to be decided as a society, and not based on market analysis. For example, the level of permissible discrimination of a policy is not determined by what people are willing to pay to discriminate or be free from discrimination; rather, discrimination is viewed as out of bounds. Similarly, the justification for bans on whaling is rooted in a widely shared ethical judgment, not on cost-benefit analysis [18].

Lastly, Cost-benefit Analysis has difficulty including democratic participation and consent [9, p. 198]. Critics are concerned that only technical analysts have decision-maker power or influence and that Cost-benefit Analysis "provides little opportunity for stakeholders to contribute to the analysis." [9, p. 198]. Nor need the consent of those who will be impacted be taken into account. Cost-benefit Analysis is viewed by some as taking a controversial view of people. People are treated as consumers, whereas decision-aiding approaches should also recognize that individuals are citizens.

Advocates of Cost-benefit Analysis acknowledge these difficulties. In response, more refined versions of Cost-benefit Analysis have been advanced. These versions try, for example, to account for the distorting effect that bad preferences and lack of information have on individuals' willingness to pay [17] and to restrict the domain of policies or contexts to which Cost-benefit Analysis should apply [16, 22]. It is unclear whether these responses successfully rebut the above objections. In our view, a more promising response to the difficulties facing Cost-benefit Analysis is to develop an alternative decision-aiding framework. We propose such an alternative in the next section.

Proposed Capabilities-based Approach

This section first outlines the original application of the Capabilities-based Approach to development economics and policy. We then discuss our proposed

application of the Capabilities-based Approach to public policy and resource allocation for hazard mitigation.

Original Application to Development Economics and Policy

The Capabilities-based Approach was developed first by Nobel Prize-winning economist Amartya Sen [23–27] and philosopher Martha Nussbaum [28, 29]. The approach was proposed for development economics and policy, where a main concern is to gauge the level of development of societies by quantifying the well-being of individuals. From a Capabilities-based perspective, the well-being and standard of living of individuals is a function of their capabilities, or in Sen's words, "the ability of people to lead the kind of life they have reason to value" [30].

Capabilities are specified in terms of functionings or "valuable acts or [...] states of being," [25, p. 30]. Functionings capture the various things of value an individual does or becomes in his or her life, including being alive, being healthy, and being sheltered. Capabilities refer to the real achievability of specific functionings. Thus capabilities are positive freedoms. The Capabilities-based Approach recognizes that individuals can be free from external interference and yet have no valuable options feasibly available. Capabilities refer to a kind of freedom that goes beyond the absence of external interference, to the real freedom individuals have to pursue doings and beings of value.

Capabilities are distinct from utilities and primary goods, other metrics of well-being. Utilities capture, for example, mental satisfaction or the pleasure or happiness of a particular individual [25, p. 58]. In practice, utilities are established on the basis of individual's preferences or choices. *A* has more utility than *B* if an individual would choose *A* over *B*. Capabilities do not focus on mental satisfaction, as do utilities, but rather on the real opportunities available to individuals. This is an advantage because focusing on mental satisfaction makes a utility-based assessment of well-being vulnerable to the problem of adaptive preferences, whereby individuals formulate expectations and preferences based on what is realistic given their situation. From the utilitarian perspective, an individual living in extreme poverty may have his/her preferences satisfied and so be said to be well-off. Because capabilities do not use satisfaction as the measure of well-being they avoid this problem.

Primary goods are all-purpose means, including rights, income, opportunities, that provide necessary resources for individuals to pursue their goals, whatever goals they may have. Unlike primary goods, capabilities focus on what individuals can *do* with their resources, and not simply on the amount of resources individuals possess. Thus capabilities can account for what Sen [25, pp. 70–75] calls the interpersonal conversion rate, or what the same amount of resources enables different individuals to achieve. Also, capabilities are valuable *ends* or components of well-being, unlike primary goods which are the *means* to well-being or freedom [26, pp. 72–76].

The United Nations (UN) and development agencies currently assess the development of societies using a Capabilities-based Approach. The Human Development Report (HDR) is published annually by the UN Development

Program and provides a picture of the level of development of countries, by measuring the standard of living within each country. This picture is based on the Human Development Index (HDI), which assesses the standard of living based on three primary capabilities (the capability to live a long and healthy life, the opportunity for being knowledgeable, and the capability of having a decent standard of living). Capabilities are not directly quantifiable. Thus, *indicators* are used to measure the level of individuals' capabilities in practice; indicators are proxies for specific capabilities [31]. So, for example, the indicator for the capability to live a long and healthy life is life expectancy at birth. The work on the Human Development Index (HDI) by the United Nation (UN) shows that quantification of the capabilities of individuals is both possible and practicable.

Proposed Capabilities-based Approach to Hazard Mitigation

From a Capabilities-based Approach, a general aim of policy makers dealing with natural hazards should be the mitigation of the impact of natural hazards on individuals' capabilities. This reflects a general concern with protecting and promoting individuals' capabilities and examining what individuals are free to achieve or be. To accomplish this aim, it is necessary for policy makers to have a method for identifying when there is a need for mitigation, and, in those cases, for comparing and ranking various policy alternatives and resource allocation strategies. In this section we describe our proposed Capabilities-based Approach method for this process.

The first step in this method is to consider whether the risk posed by a natural hazard is either acceptable or tolerable. What quality of life individuals are likely to be able to achieve in the aftermath of a hazard is the basis on which we decide whether there is a need for mitigation. To determine whether mitigation is required it is necessary to assess whether a hazard threatens a minimally acceptable or tolerable standard of living of individuals. This comparison can be done following the method developed by C. Murphy and P. Gardoni (Submitted).[3]

C. Murphy and P. Gardoni (Submitted)[3] propose a Capabilities-based Approach to acceptable and tolerable risk. In this approach, the predicted level of selected capabilities of individuals in the aftermath of a potential hazard is compared against two separate thresholds. The acceptable threshold defines the minimally *acceptable* level of capabilities attainment in principle. That is, if at all possible, the expected individuals' capabilities should not be below this threshold. Given that we are talking about future events and the level of capabilities attainment has to be predicted, the probability that individuals' capabilities will fall below an acceptable threshold should be sufficiently small. In practice, this may not be always possible, especially in the immediate aftermath of a hazard. Thus, it may be *tolerable* for the level of capabilities attainment to be below this acceptable threshold, provided (1) this situation is temporary, (2) the lower level of capabilities attainment is *reversible*, and (3) the probability of attaining a level of capabilities below a second,

[3] Murphy, C. & Gardoni, P. (2006). The acceptability and the tolerability of risks:A capabilities-based approach. *Science & Engineering Ethics* (Submitted).

tolerable threshold is sufficiently low. This second threshold delimits the absolute minimum level of capabilities attainment that should always be achieved. There is some value judgment required to specify the acceptable and tolerable thresholds, both in terms of the level of capabilities attainment required by each threshold and in terms of the probability of attainment. C. Murphy and P. Gardoni (Submitted)[3] argue that this specification can occur through internal democratic processes. The aim of such processes is to specify standards that set realistically ambitious aims levels of acceptability and tolerability for a society, given its current conditions.

The thresholds for acceptable and tolerable risk can be sensitive to distributional concerns within a society. To determine whether systematic differences exist in the level of risk faced by various groups within a society (e.g., socio-economic, racial, geographic, and occupational groups), a method of disaggregation can be used. This method, based on the technique used by the UN to assess the level of development of sub-groups within a society [32, p. 136], provides information regarding the distribution of risks. Specifically, we can determine whether any specific group is subject to risks above the acceptable and tolerable thresholds, even in cases in which the risk as a whole is acceptable or tolerable.

In general, priority should be given to addressing or mitigating the impact of intolerable risks first, followed by addressing the tolerable but unacceptable risks. Those risks that are currently acceptable should be addressed only after the intolerable risks are made at least tolerable and the unacceptable risks are made acceptable. Thus, those mitigation strategies that address these risks would be prioritized first.

After prioritizing the risks to address, the second step in our Capabilities-based Approach to hazard mitigation is to determine viable policy options for addressing the risks to be mitigated. The same principle for prioritizing which risks to address can be used to determine which mitigation strategies for intolerable and unacceptable risks are in practice viable options. *Viable* options are those that are likely to successfully bring individuals above the acceptable or tolerable levels. Public policy and resource allocation may be able to reduce the risks in one of two ways. For a hazard that is triggered by human actions, public policy may be able to reduce both the *probability* that a given hazard will occur and the *expected impact* of that hazard. In the case of landslides, for example, public policy can reduce the probability both of occurrence of a landslide, by controlling deforestation, and the expected landslide's societal impact given its occurrence, by passing appropriate zoning ordinances. Other hazards, such as earthquakes and hurricanes, are inevitable. For these hazards, mitigation strategies can consider whether the expected impact for these inevitable hazards can be reduced by, for example, revising building codes, retrofitting existing structures, changing zoning laws, or restricting land use.

Given that resources are limited and that the mitigation of the impact of hazards is not the sole objective of public policy or resource allocation, there is a need to determine which mitigation strategies to pursue from among the viable options. From a Capabilities-based Approach, mitigation strategies should be chosen on the basis of their likely *affectability* [33]. That is, we should compare the expected dollar per unit of change in the societal impact of a hazard that various mitigation

strategies might have. As noted earlier, such change can be achieved by reducing either the probability of occurrence of a hazard and/or by limiting its impacts for a given occurrence. This is done in order to maximize the return on the investment made using public resources. We should note that in the proposed approach, monetary quantification is used only as a measure of the resources allocated to mitigate a natural hazard. The monetary quantification is straightforwardly how much money is being allocated. The quantification of the consequence of that allocation is based on the likely decrease or increase in specified capability levels in the aftermath of a hazard, as gauged by indicators. We discuss the measurement of this impact in greater detail below. Following an analysis of the expected dollar per unit change in the societal impact of a hazard of various policies, a sensitivity analysis can be conducted to identify the public policy(-ies) or resource allocation strategy(-ies) that most significantly affect the predicted societal impact. Such results provide insight and guidance in the policy-making process.

The impact on society can be measured following Murphy and Gardoni [34], P. Gardoni and C. Murphy (Submitted),[4] and P. Gardoni et al. (Submitted).[2] The expected societal impact of natural hazards is identified and quantified in terms of the impact on individuals' capabilities, using a *Hazard Impact Index* (HII). Following the example provided by the HDI, the HII is developed in the following way.

First, the relevant capabilities to be used to determine the societal impact of a hazard or disaster are identified. P. Gardoni et al. (Submitted)[2] outline the criteria that need to be fulfilled in the selection process and argue for specific capabilities on the basis of these criteria. Second, appropriate indicators are selected to quantify the corresponding capabilities. As argued in P. Gardoni et al. (Submitted),[2] adequate indicators for specific capabilities need to fulfill two main criteria. An indicator should be representative of the corresponding capability, to ensure that it accurately assesses the element of well-being, or capability, in which we are interested. To be representative, an indicator should track a given capability in practice. An indicator should also be intuitively plausible in the sense that its correlation with a specific capability is reasonable.

To generate potential indicators, past engineering practice can provide a starting point. The information gathered by engineers to determine the impact of a potential hazard stems from intuitively plausible ideas about the significance of the number of fatalities and injuries on societal well-being. Past data from actual disasters, engineering predictive models, or sociological models may aid in predicting the likely value of indicators. Such predictions must account for uncertainties in the hazard magnitude and time of occurrence, as well as in the impact of the hazard on selected indicators. A confidence interval can be established that specifies the probability that the actual value of the indicator will turn out to be within a specified range. A mean can also be given to specify the expected value of a given indicator. Use of a probability distribution can provide a general picture of the different impacts different magnitudes of a hazard will have on selected indicators by describing the likelihood of each potential outcome.

[4] Gardoni, P. & Murphy, C. (2006). A capabilities-based approach to measuring the societal impacts of natural and man-made hazards. Natural Hazard Review (Submitted).

Third, the selected indicators are scaled onto a common metric, creating *Indicator Indices* (IIs), which allows the comparison among the different normalized values. Fourth, the information from each normalized indicator is combined, creating a summary index, the *Hazard Index* (HI). Finally, the value of the HI is divided by the size of the population affected by the hazard in order to put the overall impact in context, creating the HII. The HII can be seen as the hazard impact per capita.

The method outlined above provides one tool to aid policy- and decision-makers. The proposed Capabilities-based Approach accounts in a consistent way for both potential benefits and losses using the indicators of the capabilities of individuals as a metric. It provides a framework for balancing and incorporating important considerations, like fairness, efficiency and uncertainties, in the decision making process. This framework enables policy- and decision-makers to think through the problem of prioritization, clarifying the issues and the variables that must be considered.

How the Proposed Approach Addresses the Required Criteria

In this section we return to the criteria for an adequate decision-aiding approach to public policy and resource allocation discussed in the second section. We show how the Capabilities-based Approach fulfills these criteria.

1. Soundness and Consistency

The decision-aiding framework outlined above, if used in practice, would provide a principled basis for concrete policy and resource allocation decisions, as required by the first component of this criterion. Sen and Nussbaum provide the theoretical background and justification for focusing in public policy directly on the well-being of individuals, as gauged by capabilities [25, 28]. The implementation by the United Nations of a Capabilities-based Approach to development economics and policy demonstrates the possibility of concretely applying this theoretical framework in practice.

The underlying goal of a Capabilities-based Approach is protecting, restoring, and promoting the well-being of individuals, and will be achieved through the application of the proposed approach. Our proposed Capabilities-based Approach to hazard mitigation will yield concrete recommendations that positively impact the well-being of individuals in practice, by considering the acceptability or tolerability of risks, the societal impact of hazards, and whether and how mitigation strategies can reduce such impacts in a cost-effective manner.

2. Completeness

The proposed Capabilities-based Approach is complete because it accounts for the three key elements associated with policy formulation and resource allocation strategies: uncertainty, the expected impact of mitigation strategies, and the costs as well as benefits of public policies. As discussed above, uncertainty is

accounted for when determining the thresholds for acceptable or tolerable risk, the HII, and the change in the HII of various public policies or resource allocation strategies. The *impact* of mitigation strategies is determined in terms of the change in HII associated with policies. This impact could be either positive or negative, allowing us to capture the costs and benefits of strategies. Efficient allocation of resources is possible when policies are judged on the basis of the expected dollars per unit of change in the societal impact of a hazard.

3. Accuracy

As is the case in development economics and policy, the goal of mitigation strategies is to safeguard individual's well-being. Capabilities can be used to accurately assess the level of achievement of well-being of individuals in society, in part because capabilities are constitutive elements of well-being. The use of indicators that fulfill the criteria outlined in the previous section produces an accurate measure of the capabilities of individuals. Another source of accuracy is that the decisions for mitigation strategies reached from a Capabilities-based Approach explicitly account for the uncertainties inherent in policy formulation and resource allocation strategies. Finally, the Capabilities-based Approach is unbiased because it does not favor any particular groups in a society.

4. Practicality

As the application of a Capabilities-based Approach in development economics and policy shows, the proposed Capabilities-based Approach is practically implementable, given available, though limited, resources and information. A major source of the practicality of this approach stems from its communicability. Many decision-makers and policy analysts do not have the technical expertise in risk analysis. Our approach to risks, and whether, for example, they are acceptable or not, is communicable and comprehensible because the societal impact of risks is formulated in intuitively understandable terms. Capabilities capture dimensions of well-being with which individuals are familiar. The fact that this approach is currently used to assess development strategies and assess levels of development attests to its practicality.

5. Acceptability

A decision-aiding approach must be acceptable, in the sense that it is consistent with and reflects the values and priorities of the public and political institutions within a society [10, pp. 88–93; 11]. A Capabilities-based Approach accounts for considerations of distributional equity and consent. The method of disaggregation allows us to consider the impact of hazards on various sub-groups within society, enabling us to guarantee that no sub-group faces unacceptable or intolerable risks. There are two ways consent can be factored into our system. First, particular societies can specify the thresholds for acceptable and tolerable risk through a deliberative democratic process. Second, the value judgments underpinning, and

the method of a Capabilities-based Approach to decision-making, are transparent, understandable, and explicit. Protecting individuals' capabilities is the overarching aim of this approach. Because of its transparency and explicitness, a Capabilities-based Approach is conducive to public debate about both the proposed method for policy formulation and resource allocation strategies and the particular judgments reached in specific contexts. In this way, the transparency of this Approach is consistent with democratic, especially deliberative democratic, ideals. This approach can also inspire confidence in its decisions.

One final important social value is consistency in public policy both theoretically and practically. Implementing a Capabilities-based Approach in mitigation strategies would contribute to the achievement of this value, given that this approach is currently used in development policy. Consistency of approach can facilitate coordinated preventive and restorative (in the aftermath of a disaster) policy efforts in which both development and risk mitigation issues are considered together.

Conclusion

In this paper we propose a Capabilities-based Approach to guide hazard mitigation. We first present the criteria for an adequate framework for policy formulation and resource allocation decision-making, and then explain why a common decision-aiding tool, Cost-benefit Analysis, has difficulty fulfilling such criteria. We then describe our proposed approach, which requires decision- and policy-makers to consider the acceptability and tolerability of risks along with the affectability of hazards. The initial prioritization of hazards to address is made on the basis of the acceptability or tolerability of the risks such hazards pose. Intolerable and unacceptable risks should be addressed first through mitigation measures before mitigating those that are acceptable. When addressing unacceptable and intolerable risks, policies should be prioritized based on the degree to which they diminish the likelihood of occurrence and/or the likely impact of hazards at the least cost. Finally, we show how the proposed approach satisfies the required criteria, and overcomes the limitations of Cost-benefit Analysis, while maintaining its strengths.

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