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Assessing capability instead of achieved functionings in risk analysis

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A capability approach has been proposed to risk analysis, where risk is conceptualized as the probability that capabilities are reduced. Capabilities refer to the genuine opportunities of individuals to achieve valuable doings and beings, such as being adequately nourished. Such doings and beings are called functionings. A current debate in risk analysis and other fields where a capability approach has been developed concerns whether capabilities or actual achieved functionings should be used. This paper argues that in risk analysis the consequences of hazardous scenarios should be conceptualized in terms of capabilities, not achieved functionings. Furthermore, the paper proposes a method for assessing capabilities, which considers the levels of achieved functionings of other individuals with similar boundary conditions. The capability of an individual can then be captured statistically based on the variability of the achieved functionings over the considered population.

Keywords: capability; natural hazards; societal impact

Introduction

There are various valuable doings and beings that are constitutive elements of individual well-being and that individuals may or may not achieve in their lives. Examples include being adequately nourished, being mobile, and being educated. Following Amartya Sen and Martha Nussbaum, we label such doings and beings as functionings (e.g., Sen 1989, 1993, 1999a, 1999b, 2004; Nussbaum 2000a, 2000b, 2001). A person's general capability is a function of the alternative combinations of functionings that he or she has a genuine opportunity to achieve (Sen 1992). Murphy and Gardoni (2006, 2007, 2008) and Gardoni and Murphy (2008, 2009, forthcoming) have argued that risk should be conceptualized as the probability that capabilities are reduced. Furthermore, Gardoni and Murphy (2009) have proposed a Hazard Impact Index (*HII*) which aims to gauge the likely impact of hazards as the average change of an individual's capability. However, in this paper, we argue that the current mathematical formulation of the *HII* captures achieved functionings, not capabilities.

This paper responds to challenges that have been raised to both the necessity and the possibility of assessing capabilities, rather than achieved functionings. To date various applications of the capability approach in studies of development, poverty,

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and inequality have assessed achieved functionings. We argue in this paper that it is necessary to consider capabilities, not achieved functionings, in the context of risk analysis and propose a method for assessing capabilities.

There are three sections to this paper. The first provides an overview of the previous applications of the capability approach to diverse fields of study, in particular to risk analysis. The second discusses two challenges that have been raised to the use of capabilities, rather than achieved functionings. The third and final section responds to these challenges and proposes a methodology for assessing capabilities.

Risk analysis and capability

The general capability of an individual captures his or her effective freedom to achieve various combinations or vectors of functionings.[1] The capability of an individual is not only a function of or reducible to the amount of resources over which he or she has command, but depends on what he or she is able to effectively do with the resources at his or her disposal. This in turn will be influenced by his or her personal resources (e.g., talents and skills) as well as the social and material environment in which he or she acts (e.g., legal rules, social norms and customs, and the physical infrastructure and environment). Thus, capability reflects and takes into account what Sen (1999a) labels the interpersonal conversion rate, or how individuals differ in their ability to use various resources to achieve functionings.

Sen and Nussbaum originally applied the concept of capability to development economics and policy, arguing that the level of development of a society should be defined and assessed in terms of the capabilities its members enjoy (Sen 1999b; Nussbaum 2000b). Implementing Sen and Nussbaum's basic idea, annually the United Nations Development Program (UNDP) publishes the Human Development Report (HDR). The HDR uses metrics including the Human Development Index (*HDI*) to assess the development of societies on the basis of the levels of achieved functionings of its citizens (UNDP 2000).

The capability approach now addresses a much broader set of issues and range of contexts. Capabilities are used to define and assess who is the least advantaged and should be the focus of public policy directed toward the promotion of distributive justice (Wolff and de-Shalit 2007). Poverty and social exclusion in Germany have been analyzed using the capability framework (Robeyns 2006). The net societal impact of natural hazards and disasters has been defined in terms of changes in capabilities (Murphy and Gardoni 2006, 2007, 2008; Gardoni and Murphy 2008, 2009, forthcoming). The capability approach is part of the curriculum in development studies, political philosophy, 'education, disability studies, public health and gender studies, among others' (Robeyns 2006, 351).

Of particular interest for the purposes of this paper is the development of a capability approach to risk analysis. In this approach, risk is conceptualized as the probability that capabilities are reduced (Gardoni and Murphy 2009). In the context of natural hazards, the likely consequences of a hazardous scenario are conceptualized and gauged in terms of changes in individuals' capabilities. A capability approach to risk analysis provides a way to conceptualize and gauge the societal impact of natural and man-made hazards in a comprehensive and principled manner (Murphy and Gardoni 2006). There are a potentially infinite number of consequences of a hazardous scenario that could be factored into a risk analysis. The capability approach allows us to make principled judgments concerning which consequences to consider, based on

whether they impact capabilities. Because capabilities represent the freedom of individuals to achieve important dimensions of well-being, a capability approach focuses the attention of risk analysts and policy makers on what should be a primary concern when determining and evaluating risks, namely, how the lives of individuals will be affected.[2] An emphasis on capabilities, rather than achieved functionings, respects the underlying commitments of liberal governments to refrain from promoting a particular vision of the good life, but instead to ensure that a range of options of possible ways of living is available (Nussbaum 2000a). Thus, by considering how risks impact capabilities, we are in a position to see whether, and in what way, natural hazards threaten the available range of options for individuals.

As a step toward implementing this approach to risk analysis, a Hazard Impact Index (*HII*) has been proposed (Gardoni and Murphy 2009). Murphy and Gardoni (2008) also develop a capability approach to risk evaluation. A risk is acceptable if the probability is sufficiently small that capabilities will fall below a specified acceptable threshold level in the aftermath of a hazard. A risk is not acceptable, but only tolerable, if capabilities are likely to fall below the acceptable threshold in the aftermath of a hazard, provided this is temporary, reversible, and the probability is sufficiently small that capabilities will fall below an absolute minimum level of capabilities individuals should enjoy.

In the next section, we discuss two general concerns with using capabilities, as opposed to achieved functionings, in a risk analysis. Next we respond to these concerns and propose a methodology for assessing capabilities in practice.

Challenges

To date, applications of a capability approach have assessed achieved functionings (Robeyns 2006). This section surveys two arguments that have been given in defense of an emphasis on achieved functionings, rather than capabilities. In the next section we respond to these arguments, defending the necessity and possibility of assessing capabilities, rather than achieved functionings, in the context of risk analysis.

On the necessity of assessing capability

The necessity of measuring capabilities in order to assess individuals' capabilities has been questioned (Robeyns 2006; Wolff and de-Shalit 2007). In practice, the argument goes, it may be possible to infer the capabilities of individuals from information about achieved functionings. For many functionings of interest we can reasonably assume that most individuals would choose to achieve them, if they have the genuine opportunity to do so. For example, while a few individuals may choose not to be well-nourished, though they are free to be well-nourished and so have that capability, it is reasonably safe to assume that few individuals would make this choice. At the societal level and for purposes of public policy, we can safely assume that almost everyone who is effectively free to be well-nourished will choose to be well-nourished (Robeyns 2006; Wolff and de-Shalit 2007). Thus, information about achieved functionings, in this case, levels of nourishment, can provide information about capabilities, telling us who is or is not effectively free to achieve certain functionings. The cases cited in the literature, like the wealthy individual who fasts for political reasons (Wolff and de-Shalit 2007, 64), in fact capture outliers and do not show the necessity of assessing capabilities instead of achieved functionings.

On how to assess capability instead of achieved functionings

Doubts surrounding the practical possibility of measuring capabilities have also been raised. To understand these doubts, it is necessary to understand how achieved functionings are assessed. The current formulation of the Human Development Index (*HDI*), the Hazard Impact Index (*HII*), and the Disaster Impact Index (*DII*) are constructed in four steps (UNDP 2000; Gardoni and Murphy 2009, forthcoming). First, the capabilities that are most relevant for a particular subject (e.g., development, risk analysis) are selected (e.g., in development the ability to live a long and healthy life, the opportunity for being knowledgeable, and the ability to have a decent standard of living). Second, indicators are used to quantify the level of each functioning achievement. Third, each indicator is converted into an index by a process of scaling. Finally, the indices are combined, creating an aggregate measure of achieved functionings.

Figure 1 shows an illustration of the current formulation of the *HII* (and similarly of the *HDI* and *DII*). The far left column of the chart lists the functionings under consideration (F_1, F_2,…,F_k). Functioning F_1 might be achieved at levels F_{11}, F_{12},…,F_{1q}; functioning F_2 at levels F_{21}, F_{22},…, F_{2q}; functioning F_k at to levels F_{k1}, F_{k2},…, F_{kq}. So, for example, an individual $P^{(i)}$ achieves F_{12} for functioning F_1, F_{2q} for functioning F_2, and so on, up to F_{k1} for functioning F_k. The achieved functionings of individual $P^{(i)}$ are then converted into *k* indices (one per achieved functioning): $I^{(i)}{}_1$, $I^{(i)}{}_2$,… $I^{(i)}{}_k$. The same process is repeated for all individuals considered $P^{(1)}$,…, $P^{(n)}$. For each functioning considered, an average of the indices over all individuals is then computed (Avg.$[I^{(i)}{}_k]$, $i = 1,\ldots,n$). Finally the *HII* is computed by combining all the averages.

There are three limitations with this current formulation of the *HII*, *DII*, and *HDI*. First, the construction of the *HII*, *HDI*, and *DII* captures achieved functionings, not capabilities. Each represents an average individual's achieved functioning over a specified population group on a scale from 0 to 1. Such scaling expresses the average achieved functioning level in relation to the average functioning achievements of others groups or societies. However, if one wants to use this formulation to assess capabilities, the specification of such scales may be too complex to be practicable. As Wolff and de-Shalit (2007) note, capabilities are counter-factuals and so capture the different alternatives that, on average, are available to individuals or could have been available 'had different choices been made'. To accurately represent an individual's capabilities, a number of scales would be needed, each of which indicates the various

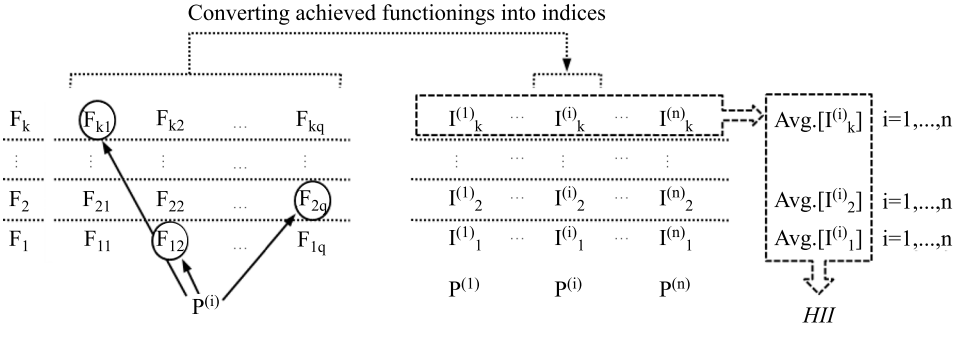

Figure 1. Illustration of the current formulation of the *HII*, *HDI*, and *DII*.

levels of functionings individuals would be in a position to obtain, given the choices they make, resources available, and overall social and material context.

Second, this formulation only considers average levels of achieved functionings and the indices only reflect average values over the group or sub-group of the population considered. However, this fails to address the issue of variability. To have a more complete picture of societal well-being or the societal consequences of a hazard, defined in terms of the well-being of individuals, it is important to account for the variability in the level of achieved functionings across an entire population or within a sub-group of the population. Using only average values does not distinguish between two different cases, one in which every individual reaches the same level of achieved functionings and one where half of the population is largely below the average level and half largely above. A process of disaggregation (Fukuda-Parr and Kumar 2003; Gardoni and Murphy 2008, forthcoming; Murphy and Gardoni 2008) has been proposed to investigate potential differences among sub-groups of a population, by dividing the population into sub-groups and calculating the *HII*, *HDI*, or *DII* for that sub-group. However, important variations are not captured if variations in individual well-being do not correlate with how sub-populations are defined but are more random in nature. Further, differences within sub-populations will not be represented by the average number provided by the construction of the *HII*, *HDI*, and *DII* for a sub-population.

Third, in assessing what individuals could have achieved or could achieve, it is also necessary to take into consideration the interaction among particular functionings. In practice, an individual $P^{(i)}$ cannot choose to achieve any possible combination of functionings. Choosing to achieve one functioning often limits an individual's ability to achieve another functioning. Further, the choices other individuals make may impact other individuals' capabilities. For example:

> Two spouses may each individually have the capability of holding demanding jobs which are incompatible with large caring responsibilities, but if these spouses also have small children or other relatives with extensive caring needs, then at best only one of them may effectively realize that capability. (Robeyns 2006, 354)

In practice, an individual can only choose among a set of vectors of achieved functionings. Because the current methodology considers functionings in isolation, rather than vectors of functionings, the current methodology fails to sufficiently acknowledge this interconnectedness.

Assessing capability

In this section, we respond to the two challenges discussed above. We argue for the necessity of considering capabilities in the context of risk analysis and natural hazards and propose a methodology for assessing capabilities.

On the necessity of assessing capability

For certain purposes, like assessing the least advantaged in society, it may be sufficient to consider achieved functionings. This is because the functionings frequently used to assess the least advantaged are basic, functionings that we may safely assume individuals would normally choose to achieve, if they have a genuine opportunity to do so.[3] Capabilities may thus be accurately inferred from the levels of achieved

functionings. Similarly, in the context of natural hazards, when predicting the impact on capabilities of medium or large hazards in the emergency phase (the time that immediately follows a disaster), the functionings of interest are often basic; therefore, achieved functionings can provide sufficient information about capabilities. For example, being sheltered is a functioning that we may reasonably assume that individuals would choose to achieve if they have a genuine opportunity. We can reasonably presume that if some individuals in the emergency phase in the aftermath of a hazard are not sheltered this is because they lack the capability to be sheltered. Thus, the presumption that individuals will choose to achieve certain functionings if they have a genuine opportunity to do so also applies to determinations of the societal impact of a disaster in the emergency phase.

However, information about functionings achievement provides only a coarse assessment of the medium- and long-term impacts of a hazard on capabilities. The medium- and long-term impacts of large hazards, or the impact of smaller hazards, affect non-basic functionings or basic capabilities in a more subtle manner. Non-basic functionings are those that we cannot reasonably presume that individuals would choose to achieve, if given a genuine opportunity. Thus, we cannot infer the capabilities of individuals simply by considering functionings achievement. Considering only achieved functionings for non-basic capabilities would lead us to either under- or overestimate the societal impact. It would only capture changes in what individuals choose to achieve but would not provide an accurate picture of how, or whether, the capabilities of individuals change.

For example, consider an individual who before a hazard has the capability to achieve a functioning in different ways, A, B, and C, and he or she chooses A. If, in the aftermath of a hazard, the choice of option C is not available anymore, he or she will still choose A. So in terms of achieved functionings there is no change. However, the actual options available, and so the freedom of that individual, are reduced. Thus, if we only consider achieved functionings, we underestimate the actual impact of a hazard. Conversely, if, as part of a recovery effort, a new option D is made available, it is important to recognize that the freedom of the individual has changed, even if the individual still chooses A. In this case, only considering achieved functionings overestimates the impact of a hazard and fails to recognize some positive impacts of the hazard that mitigate its overall impact. It is important to capture the overall net societal impact of a hazard accounting for both the negative impacts and also the new opportunities that a hazard might bring (Gardoni and Murphy 2009).

As an example of what A, B, and C could be, consider the capability of being mobile. A, B, and C could represent alternative ways that are available for an individual to go to work (e.g., alternative routes or transportation methods). Due to the impact of a hazard, option C might not be available at least for a period of time. While an individual might still choose route A, as he or she did before the hazard, traffic will likely increase, given the reduction in other available routes. This will impact the level of mobility the individual is free to achieve. On the other hand, if as part of the recovery reinvestment or mitigation strategy a new route opens, then even if he or she chooses A the traffic will likely be less than before the hazard, thereby enhancing mobility.

How to assess capability instead of functionings

Having discussed the need for assessing capabilities instead of functionings, we now want to propose a methodology for gauging capabilities. The fundamental idea is that

to assess the capability of an individual we need to consider both his or her choices and achieved functionings, and what other individuals with similar boundary conditions have chosen and achieved. Looking at the chosen vectors of achieved functionings by individuals from an appropriately defined societal sub-group provides us with a realistic picture of the range of options and genuine opportunities open to an individual similarly situated. From this information we can develop a sense of the choices that such an individual could make and the functionings he or she could achieve. By looking at what others similarly situated have been able to achieve, our judgment about what individuals could achieve does not involve mere speculation or stipulation, but is grounded in reasonable considerations. In what follows, we discuss the methodology for making such assessments of capabilities.

First, as noted above, in practice an individual $P^{(i)}$ can only choose among a set of vectors of achieved functionings, $V^{(1)},\ldots, V^{(n)}$. This is shown in Figure 2. For example, an individual can choose $V^{(1)}$, which entails choosing F_{1q}, $F_{21},\ldots, F_{k1}$, or $V^{(i)}$, which entails choosing F_{12}, $F_{2q},\ldots, F_{k1}$, and so on up to $V^{(n)}$, which entails choosing F_{11}, $F_{2i},\ldots, F_{kq}$. Focusing on vectors, rather than isolated individual functionings, provides a more representative picture of the actual opportunities open to an individual. It is important to account for this vector-structure of the possible choices when computing the *HII*, *HDI*, or *DII*. Therefore, after transforming the achieved functionings into indices, we need to compute the *HII*, *HDI*, or *DII* at the individual level and then determine the level of achieved functioning across individuals. This process will provide a more accurate picture of the freedom of individuals.

Second, in evaluating the capability of an individual we need to consider two dimensions. The first is the quality of the options open to an individual. The second is the extent of the freedom open to the individual who is choosing. To ascertain the general capability of an individual, then, the challenge is to develop a method for determining the quality and range of vectors that are available to him or her. The quality of vectors tells us about the levels and kinds of functionings that can be achieved, and so the quality of the opportunities available to an individual. The range of vectors provides information about the extent of the effective freedom of an individual, or scope of his or her opportunities. In our view, this should be done by considering the achieved vectors of functionings among individuals with similar boundary conditions, or those who are similarly situated, who form a homogeneous pool. For a homogeneous pool of *n* individuals, we can assess $HII^{(1)},\ldots, HII^{(i)},\ldots, HII^{(n)}$. Then, we can

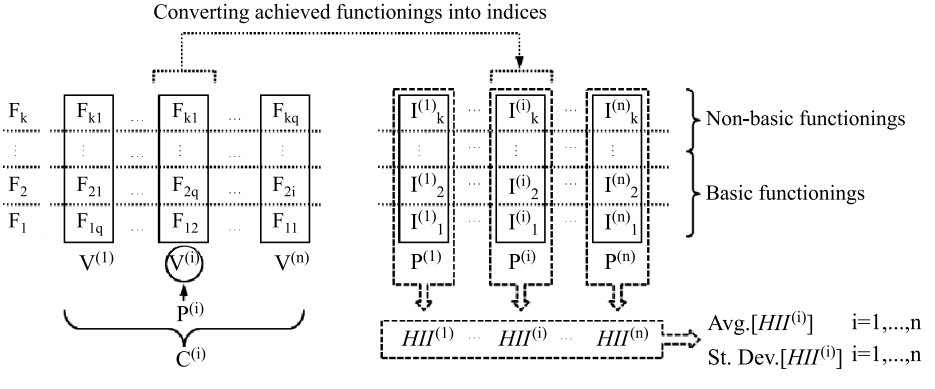

Figure 2. Illustration of the proposed formulation of the *HII*, *HDI*, and *DII*.

compute the statistics of the *HII* for this pool of individuals by taking the average of the $HII^{(i)}$, $i = 1,\ldots,n$, and its standard deviation. The $HII^{(j)}$ is a measure of a vector of available options for individual i in the same sub-group as individual j. Therefore, the average *HII* provides information about the quality of the choices, or level of functionings achievement, open to individuals in that sub-group, which is one of two components of $C^{(i)}$. The standard deviation of the *HII* accounts for the variability of the composite indices, or the range of opportunities that members of the sub-group have. Therefore, the standard deviation is a measure of the breadth of opportunities, which is the second component of $C^{(i)}$. Using the standard deviation is a simple way to capture the variability into a single number. To determine the overall capability for a general population, we can compute the weighted average of the $C^{(i)}$ for the various sub-groups within a population, where the weights are proportional to the size of each sub-group.

Other advocates of the capability approach have pointed out the need to use statistical information when assessing capabilities. Wolff and de-Shalit (2007), for example, suggest that we look at trends over time based on historical data to assess the security with which functionings are achieved. In their proposed use, we can infer the security of functionings from the trends we see for certain sub-groups over time. In their words:

> The fact that I have a job today says nothing about whether it is a day's casual work or a sinecure for life. However, taking a wider view and looking at the individual's social circumstances or context immediately provides more information. Indeed, statistics will provide much of what we need. Imagine that among certain groups – perhaps the young, recent immigrants, or the low paid – there is a high degree of mobility in employment or housing, with those moving jobs or homes also experiencing periods of unemployment or homelessness. This, then, gives a prima facie reason to believe these functionings are not achieved securely by people within these groups… In general, then, although individual functioning is not an indicator for the degree of security, statistics often can be. (Wolff and de-Shalit 2007, 116–7)

Their use of statistics is, however, different from the one proposed here. The purpose of our use of statistics is to assess variability within a group in terms of the choices that members of that group make. Such information is different than looking at historical trends where the purpose is to gauge stability in the achievement of functionings over time.

There are two components to the overall standard deviation of a composite index: the variability in the sub-vector of basic achieved functionings and the variability in the sub-vector of non-basic achieved functionings. These two components can be assessed by considering the standard deviations corresponding to each sub-vector of achieved functionings as shown in Figure 2. As we noted earlier, for basic capabilities, which refer to functionings which nearly all individuals would choose to achieve if in a position to do so. A large standard deviation is a problematic sign of inequality, for it suggests a large variability in the ability of individuals to achieve basic functionings. In the case of basic functionings, the goal is to see a large mean and a small standard deviation.

For non-basic capabilities, we cannot safely assume that all individuals will choose to achieve their corresponding functionings, even if free to do so, because of differences in the kinds of lives individuals desire to choose to achieve. For this group, we must assess the capabilities (or breadth of available options) by looking at the variability of the sub-vectors of actual achieved functionings of individuals within the same societal

group or sub-group. The variability within a properly defined sub-group of the population reflects the breadth of the capabilities individuals might choose to achieve, which is captured by what other individuals with similar boundary conditions have chosen. For such non-basic capabilities, a large standard deviation in the achieved functionings is desirable, because it suggests the greater freedom of individuals to achieve certain functionings.

Thus, for defined groups, the goal should be to maximize variability for non-basic capabilities and minimize variability within sub-vectors of basic capabilities and among defined groups of those with similar boundary conditions. Reducing the between-group variability is a way to maximize the relative equality of groups within a society. A good/just society would need to maximize the within variation relative to the non-basic capabilities in order to maximize freedom and minimize the between-group variation in order to maximize equality. This would show that all groups within a society are free to choose from among multiple functionings, and that there are no significant differences in the freedom that sub-groups enjoy.

Homogeneous pools cannot be defined too narrowly, which would limit the actual variability within one group, nor too broadly, which would include spurious variability due to the non-homogeneity of the group. Potential definitions of homogeneous groups could be on the basis of age, gender, and socio-economic status. Furthermore, a sensitivity analysis can be done by repeating the analysis with different definitions of the homogeneous groups to assess the dependence of the outcomes of the analysis on the grouping.

Finally, in the context of risk analysis the impact on individuals' capabilities and the variability seen within those who share similar boundary conditions must be predicted. One method is to estimate/predict the value of the impact of future hazards by computing the impact of past disasters on individuals' capabilities, using available data. Such information about the impact of past disasters provides a reference to predict the impact of similar, future hazards. The computed composite index for past disasters can then be used to estimate the conditional Probability Density Function (PDF), $P(HII|H,M)$, which describes the likelihood of each potential outcome of *HII* for a given hazard type, H, of magnitude M. The probability of future societal impacts can then be written integrating out H and M using the Total Probability Rule (Ang and Tang 2007), as:

$$P(HII) = \int P(HII \mid H, M) P(H, M)\, dHdM \tag{1}$$

where $P(H,M)$ is the joint PDF of (H,M). This function provides us with information about the likelihood of the impact of various hazards of various magnitudes on society. The joint PDF, $P(H,M)$, can be estimated purely based on, for instance, meteorological/seismological considerations and is decoupled from the analysis of the societal impact of a hazard. Statistics of the *HII*, like the mean and the standard deviation, can also be computed using available data from past disasters.

Conclusion

In a capability approach, risk is conceptualized as the probability that capabilities are reduced. In particular, in case of natural hazards, the likely societal impact of a hazard can be gauged in terms of likely changes in individuals' capabilities. This paper responds to two objections to the adoption of a capability approach in risk analysis,

which question the necessity and possibility of assessing capabilities rather than achieved functionings. We argued that a capability approach to risk analysis is both necessary and possible. The capability of individuals in the aftermath of a hazard cannot typically be inferred by considering their corresponding functionings achievement; explicit consideration of capability is necessary. Further, we developed a probabilistic framework to assess the capability of individuals, which considers the level of functionings achievement of other individuals with similar boundary conditions. Capabilities can be captured statistically based on the variability of these achieved functionings. The proposed formulation can also be used as a guide for the promotion of justice within a society. A just society maximizes the variability within groups and minimizes the variability among groups.

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Notes

1. We can also speak of particular capabilities. If an individual has a particular capability, then he or she has a genuine opportunity to achieve that particular doing or being.
2. The freedom to choose which functionings one will achieve, and the enjoyment of a rich range of capabilities, are also themselves important elements of individual well-being.
3. Examples of basic capabilities in our sense include the capability to have adequate shelter, avoid injuries, and be adequately nourished. Our use of the notion 'basic capabilities' departs from both Nussbaum and Sen. Nussbaum defines basic capabilities as 'the innate equipment of individuals that is the necessary basis for developing the more advanced capabilities, and a ground of moral concern' (2000b, 84). Sen defines basic capabilities as capturing 'the ability to satisfy certain crucially important functionings up to certain minimally adequate levels' (1993, 40).

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