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ORIGINAL PAPER

Challenges and Opportunities for Economic Evaluation of Disaster Risk Decisions

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Abstract Decision-makers today are required to assess disaster risk management options in increasingly complex and uncertain environments. Disaster risk management typically involves significant investment to mitigate low probability or highly uncertain events. We argue that under these circumstances existing economic evaluation toolkits do not adequately support decision-making. Our paper outlines the key economic evaluation tools used in decision-making and, in turn, advances a research agenda for future development and application of these approaches. Priority challenges to be addressed include resilience thinking, multi-capital assessment, valuing the future, accounting for distributional equity, social appetite for risk, and deep uncertainty. We also recommend a strong focus on capacity and capability building to improve the risk literacy of decision-makers.

Keywords Disaster risk · Economic evaluation · Decision-making · Deep uncertainty · Cost benefit analysis · Resilience

Introduction

We live in a complex world with a plethora of known and unknown risks to manage and an innumerable number of management options available. The expectation on decision makers to better manage disaster risks continues to grow. In part this reflects the increasing vulnerability of global communities to disasters with increasing urbanization and expansion of social and economic capital at risk. Moreover, the threat of some natural disasters is likely to be exacerbated by climate change. Several economic evaluation approaches have been developed

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to help decision-makers assess the relative merits of disaster risk management options, however these are often inadequate in informing decision-making when applied to low probability, high consequence events.

This paper highlights several key challenges, and hence opportunities, associated with the development and application of existing economic evaluation approaches in disaster risk management decision-making. These challenges and opportunities have been identified in-the-course of working on several large-scale multi-disciplinary research programmes.[1] In doing so, we present a research and policy agenda that will help to transport information provisioning and current decision making into the era of resilience; ensuring that decision-makers have the right tools to make informed and appropriate risk management decisions.

Our paper begins with a very brief review of the existing economic evaluation approaches as principally applied in disaster risk management decision-making. We then provide a research agenda for advancing the development and application of these approaches by focusing on key challenges.

Economic Evaluation Approaches

Over the last three decades, cost-benefit analysis (CBA), also termed social cost benefit analysis, has been the dominant technique for appraisal of decisions regarding public sector resource allocation (cf. Atkinson and Mourato 2008). Cost effectiveness analysis (CEA), a derivative of cost-benefit analysis, is also commonly applied when comparing options with the same or similar defined benefit.[2] These techniques are supported by numerous academic texts and manuals, including those that relate broadly to all types of public good decision-making (e.g. Boardman et al. 2014; Johansson and Kristr m 2016; Quah and Toh 2012), as well as texts with a specific disaster risk management focus (Deloitte Access Economics 2013; Environment Agency 2010a; FEMA 2015; Mechler 2005). Importantly, many examples exist of where CBA is supported or directed, even mandated, by regulations (including legal precedents) and public sector best practices guidelines.[3]

Behind the enduring appeal of CBA and its derivatives is ‘simplicity’ – total benefits, less total costs, equals net benefits. It is thus easily understood. By corollary, CBA is also a well-established, well-documented and open methodology. This approach is however subject to limitations, including imperfect valuation methods, sensitivity to assumptions regarding inter-generational preferences (e.g. discount rate), tendency to favour monetized (often tangible market) costs and benefits, and inconsistent and often inadequate treatment of non-quantifiable (often intangible non-market) costs and benefits (Atkinson and Mourato 2008; Boardman et al. 2014; Bonzanigo and Kalra 2014; Florio 2014).

[1] QuakeCoRE (https://www.quakecore.nz), Resilience to Nature’s Challenge’s (https://resiliencechallenge.nz) and the Natural Hazards Platform (https://www.naturalhazards.org.nz/).

[2] CEA is frequently applied when an action must be undertaken in response to an issue i.e. a ‘do nothing’ option does not exist.

[3] In New Zealand, for example, the Treasury has produced the ‘Guide to Social Cost Benefit Analysis’ with the explicit purpose of outlining steps and organizing principles for advisors to public decision makers to follow. An analogous CBA guide exists in Australia (Department of Prime Minister and Cabinet 2016). Similarly, in the UK the *Green Book* (HM Treasury 2011), which provides guidance to public sector bodies on appraisal of policies, programmes and policies, incorporates CBA as an important component of the appraisal process.

Multi-criteria analysis (MCA) is frequently cited as the major alternative decision-making approach (cf. Environment Agency 2010b), particularly when assessing options that involve complex effects and where project objectives, criteria and alternatives encompass diverse and possibly conflicting values (Doumpos and Zopounidis 2014). The method is, however, often criticized for being too subjective (Dodgson et al. 2009; Huang et al. 2011; Keeney and Raiffa 1976; Watkiss et al. 2015) and, therefore, is often treated as a component of a wider evaluation process that includes CBA.

The literature on economic evaluation continues to evolve with a variety of new approaches promoted in recent years (e.g. Bowman and Moskowitz 2001; French et al. 2005; Rubinstein 2002; Kalra et al. 2014). For the most part however, these have been applied as refinements, enhancements or improvements of existing CBA/MCA approaches, rather than constituting outright replacements.

Key Challenges and Opportunities

Resilience Thinking

The resilience perspective is increasingly used as an approach for understanding social systems. Differences in resilience are said to underlie differences in the capacity of individuals and communities to cope and recover following disasters (Keating et al. 2014; Noy and Yonson 2016). Strongly based on systems and systemic thinking, the resilience perspective emphasizes dynamic and non-linear interactions (including feedbacks) across time and through space. This includes acknowledging that periods of gradual change will interplay with periods of rapid change, creating emergent behaviour, inevitable uncertainty and surprise (Folke 2006). Resilience-building management strategies are thus not only based on risk reduction, but also on living with and continually adapting to risk (Mechler 2016).

Although society is continuing to define just what a resilience paradigm means for public decision-making, one key characteristic is a movement from planning just for 'known unknowns' towards planning also for 'unknown unknowns'. A further feature of this systems-orientated perspective is that it helps us to recognize that many, if not all, of the major socio-economic and ecological problems we face are inextricably interconnected. As aptly stated by one of the pioneers of systems thinking "[m]anagers are not confronted with problems that are independent of each other, but with dynamic situations that consist of complex systems of changing problems that interact with each other" (Ackoff 1979, p.93).

Presently, many important public good decisions occur in a management cycle that is predominantly linear and single issue focused i.e. identification of a need for change, compilation of a set of potential intervention options, and evaluation of options (c.f. Treasury 2014). An important question is what groundwork should we undertake now to ensure that whenever potential intervention options are identified, minds are open towards creative solutions. These solutions must be adaptable in the face of many outcomes and tackle interconnected problems in a systemic way. Subsequently, evaluation approaches need to be able to identify and 'value' any resilience-building outcome. This may be complex given that resilience building will often consist of a portfolio of initiatives implemented across time and through space, some of which may be relatively intangible (Mechler 2016).

Another key resilience message is the importance of flexibility, continual learning and adjustment. In the context of socio-ecological research, the concept of 'adaptive management'

has been emphasized (Gunderson 2002; Walters 1986). Adaptability implies not only an ability for social systems to respond to change, but also an ability to influence and shape the system itself. These themes all suggest a governance system that promotes monitoring of decision outcomes, re-evaluation, and a willingness to experiment and innovate. Unfortunately, the political reality is that such strategies can be difficult to implement, simply because the case for re-evaluation and revision may be difficult to communicate to the public, often requires extended timeframes, and may be interpreted as failure. There is a need to consider how governance and institutional mechanisms can be reformed to better engender adaptive management. Encouragingly, relevant mechanisms have already been put forward in the Sendai Framework (United Nations 2015) which calls for building awareness and knowledge sharing through information dissemination, periodic assessment and reporting, and promotion of mutual learning and exchange of good practices.[4] Significant further work is however required.

Multi-Capital Assessment

A key challenge in the ongoing development and application of the existing economic evaluation techniques is the explicit inclusion of multi-capital considerations into the assessment of costs/benefits or effects. Risk management options must meet multi-facetted goals: we are not simply focused on net economic benefits, but often also on achieving social, cultural and environmental objectives. In the end, a key premise underpinning CBA and MCA, as applied in risk management decision-making, is the desire to at least maintain, and potentially enhance, 'societal wellbeing' when selecting a preferred management option. What exactly is meant by societal wellbeing has been hotly contested over at least the last three decades. We have, however, seen a transitioning from purely economic considerations (e.g. economic welfare) to more holistic measures capturing multi-capital provisioning of goods and services for wellbeing i.e. covering inter alia manufactured, financial, social, human and natural capitals. For example, current multi-capital policy evaluation frameworks include the UNEP Environmental, Social and Economic Sustainability Framework (UNEP 2015), and the NZ Treasury Higher Living Standards (The Treasury 2015). Existing economic evaluation approaches are yet to fully embrace multiple capitals in their assessment and reporting[5] despite a clear mandate to do so.

Valuing the Future

Discounting is common practice in economic evaluation. It is, however, often criticized for devaluing the impact of decisions on future generations (Atkinson and Mourato 2008; Hepburn 2007; Pearce et al. 2003). Discount rates are used to ensure that future costs and benefits can be expressed as a Present or Net-Present Value (EPA 2010). The use of 'recommended' discount rates often means that costs or benefits occurring more than 25–35 years into the future have minimal value. This has a strong influence on the evaluation of disaster risk management options, as mitigation of low probability, high consequence events

[4] *Sendai Framework for Disaster Risk Reduction 2015–203.* United Nations, para [27, 28]

[5] Triple bottom line reporting and full-cost accounting are examples of the transition towards more holistic evaluation methodologies which share many of the features of CBA, but are yet to fully gain traction in decision-making.

often require significant up-front investments, but returns are achieved over long time horizons. We can note that there is a growing movement to change discount rates so that they reduce over time. In the UK, for example, CBA assessments that evaluate periods greater than 50 years and involve substantial and irreversible transfers between generations, can apply a significantly reduced set of discounting rates (Lowe 2008). There is a great deal of inconsistency, however, in the way discount rates are treated across nations as well as between government agencies within nations.

The question for researchers and policy makers is: how do we appropriately value impacts occurring in the future and whose preference sets are important in that valuation? The discourse on sustainability has provided some insightful views on how we may approach such questions (e.g. Neumayer 2013). Particularly problematic is our inherent tendency to assume that the current generations' value set (i.e. preferences) will apply to all future generations. Nevertheless, there is still much work to be done on how this may translate into best practice in the context of disaster risk management evaluation and decision-making.

Distributional Equity

Over the last decade public awareness has heightened regarding the potential social and economic consequences of growing inequality. Wilkinson and Pickett (2009), for example, present a comprehensive case for managing and reducing income inequities within societies. The impact and aftermath of events such as Hurricane Katrina have showed how disasters can impact unfairly on lower socio-economic sectors of society (Elliott and Pais 2006; Masozera et al. 2007).

Despite growing evidence of inequality within our communities, existing economic approaches largely continue to focus on total costs and benefits and thus do not account for distributional inequalities. There is often an implicit assumption that those who lose out will be compensated by those who benefit. If, however, the losers continue to be subjected unfairly to losses then societal inequalities will be exacerbated. While it is possible to adjust existing evaluation approaches to assess costs and benefits for different groups within society (Florio 2014), this is not widely practiced (Boardman et al. 2014). Ideally any enhancements should also show the transition pathway for each stakeholder group through time as costs and benefits are not necessarily distributed evenly through time.

Social Appetite for Risk

Risk and uncertainty about the future are related concepts. Sometimes risk has been defined as a form of uncertainty, i.e. where one is willing to assign probabilities of occurrence to the range of different uncertain future outcomes or 'contingencies' that may occur (Boardman et al. 2014). To date much of the work on extending evaluation approaches for risk/uncertainty has focused around testing and communicating the reliability of our estimates of benefits (and costs) associated with management options. Although uncertainty ranges may be included in the exercise, the actual values computed and reported of benefits/costs are typically the 'expected values',[6] without explicit consideration of the option value or in other words 'insurance benefit' associated with different options (Boardman et al. 2014).

[6] The expected benefits of a policy are calculated by taking the weighted average of the benefits over all contingencies, where the weights are the respective probabilities that the contingencies occur (Boardman et al. 2014).

A disadvantage of this approach is that it gives no explicit consideration to the relative attractiveness of different options based on society's appetite for risk. This approach explicitly assumes that social decision making is *risk neutral*. Although significant research in behavioural economics has demonstrated that humans are not indeed risk neutral (e.g. Kahneman and Tversky 1984), a frequently given justification is that governments or other public bodies can pool the risks and uncertainties from many projects and also spread risks and uncertainties amongst many individuals (c.f. Staehr 2006). Such arguments, however, often fail when applied to decisions regarding disaster risk management. Disaster events tend to be of low probability but very high consequence, and the widespread nature of disasters means that there is limited ability to pool risks over individuals.

Accepting that better incorporation of risk preferences in the evaluation of disaster management options is a priority, there are two avenues that can be further explored. The first is to try and internalize risk preferences within the metrics used for evaluation. Expected utility theory (Smith and Vignaux 2006; Wallenius et al. 2008), option price analysis (Smith 1984) and prospect theory (Kahneman and Tversky 1979) are existing approaches, but to date these are not typically applied at practitioner level to assist in the comparison of options involving differing disaster risk profiles. A lack of prior research that provides analysts with readily available information to confidently describe risk preferences in the context of disasters is generally the limiting factor to wider application.[7]

Even if it is not feasible to ascertain and quantify community risk preferences in an evaluation, an avenue that can at least be explored is the provision of better information to decision makers on the relative 'riskiness' of different options. A matter requiring further thought, however, is whether the metrics typically employed to measure and communicate risk/uncertainty are those best suited to the analysis of disaster risk. We note routinely applied statistical metrics are often based on a normal distribution, whereas a 'fat -tailed' probability distribution is often more representative of the potential impacts of natural disasters.

Deep Uncertainty

Several techniques have been developed to deal with epistemic uncertainty – that is the uncertainty we recognize and can model. Monte Carlo Analysis, for example, is a process by which uncertainty in model input variables is translated to measures of uncertainty for model results. This technique only narrowly tests the decision outcome within the parameters and constructs of the original assessment and does not account for the ontological uncertainty of an unknown future.

Recent literature suggests that there has been a paradigm shift away from seeking decisions that are necessarily 'optimal', and instead to decisions that are 'robust' in the context of 'deep uncertainty' (Groves and Lempert 2007; Kalra et al. 2014; Maier et al. 2016). Per Hallegatte et al. (2012, p.4) 'deep uncertainty' occurs "due to the presence of one or more of the following elements: (1) 'Knightian' uncertainty: multiple possible future worlds without relative known probabilities; (2) Multiple divergent but equally-valid world-views, including values used to define criteria of success; and (3) Decisions which adapt over time and cannot

[7] A related issue that is sometimes encountered is debate over whose risk preferences should count in decision making. Following the 2010–2011 Canterbury earthquakes in New Zealand, many residential properties were subject to risks from rockfall. The Council's decision to deem certain dwellings as uninhabitable was highly controversial given that many of the residents were prepared to live with the risk.

be considered independently". Robust options or strategies are those that perform well when compared with alternatives across a wide range of different assumptions and plausible futures (Lempert and Collins 2007). While it has been recognized that decision-makers can continue to draw on traditional decision metrics when seeking robust decisions in the context of deep uncertainty, such as Net Present Value from CBA, the decision-making process is likely to vary from traditional methodologies (Kalra et al. 2014). The need to test options under a wide range of plausible futures, in a context where parties to the decision differ in how they value alternative outcomes, implies that decision-making will often be more successful when built upon participatory processes and close interactions between experts and decision-makers (Kalra et al. 2014).

Given that scenarios have become a typical means for quantifying uncertainty in the face of multiple plausible futures (Maier et al. 2016), there are also strong links between the concepts of deep uncertainty, robustness and scenario planning. The latter is a decision-making tool that, since the 1990s has enjoyed a resurgence in popularity. Premised on the idea that the future is fundamentally uncertain, scenario planning has been described as the process of creating a coherent and credible set of stories of the future as a mechanism for testing plans or projects, prompting public debate or increasing coherence (Ringland 2006).

Like many issues facing public good decision-makers, the potential scenarios and assumptions that could be tested in evaluation of disaster management options are vast. When evaluating options for infrastructure investments that mitigate consequences of natural hazards, for example, there are not only different types of hazards for consideration, but also different levels of potential intensity for each hazard, and potential interactions between hazards i.e. cascading hazards. Added to this, there are many different factors influencing the way in which communities may change over time (e.g. population migration, land use change, technology), all of which are uncertain and influence community vulnerability. Even the infrastructure investments themselves (e.g. through budgetary constraints, promoting land use change) may stimulate a reorganization of the socio-economic system under consideration.

Understanding how hazard events intersect with community vulnerability and transform into societal impacts is complex, and will often require input from a multi-disciplinary team of experts, employing a range of analytical methods. Given the data and resources involved, it is not surprising there is a tendency in decision making processes to select only a small set of often poorly constructed scenarios for evaluation. We feel that urgent attention needs to be given to the development of guidelines for scenario development and storytelling that acknowledge not only constraints on resources, but also the need to reach robust outcomes (cf. Watkiss et al. 2015).

Capability and Capacity Building

The effective evaluation of disaster risk decisions is not only reliant on careful and robust development and application of evaluation approaches; it also requires a high level of risk literacy amongst practitioners and decision-makers. Our research has highlighted that levels of risk literacy amongst regional and national decision-makers varies considerably including evidence to suggest the quality of supporting analysis and decision-making is negatively impacted.

There is a tendency, using current evaluation approaches, for decision-makers to be absent from the evaluation process. Traditional application of methods like CBA result in decision-makers being presented with ranked options. Decision-makers are divorced from the analysis

and rely on the analyst's description of assumptions and processes. No matter how good the analyst, they are invariably working with limited understanding of the decision-drivers and complex interactions that the decision-maker is managing. Emerging methodologies, such as scenario testing and robust decision-making, tend to bring the decision-maker into the evaluation process so that they can better understand the dynamics of different assumptions and their alternative future pathways with their understanding of the decision context.

There is an ongoing requirement to build capability and capacity in the use of evaluation approaches to ensure rigorous supporting analysis and decision-making. Importantly, this should not just focus on 'correctly' producing templated outputs, but using the evaluation approaches to assist analysts and decision-makers throughout the evaluation process – adding transparency, explanation and information at multiple scales for multiple stakeholders.

Conclusions

A key objective of this paper has been a call to action for researchers to better support decision-making in the context of disaster risk management. Researchers have a vital role in (1) gathering, interpreting and synthesizing information (e.g. to provide evidence on community risk preferences), (2) providing competencies for the ongoing development and expansion of economic evaluation approaches to more adequately address the challenges described in this article, (3) delivering analytical skills to undertake evaluation of case-specific risk management options, and (4) providing education and support for decision-makers to enable them to confidently make decisions in the complex and uncertain world we live in. Together these tasks necessitate a coordinated multi-disciplinary effort.

The efficaciousness of disaster risk management clearly also reflects the underpinning policies and procedures put in place for such decision-making. Any economic evaluation approach presents decision-makers with criterion that are to some extent non-objective. Even a relatively simple CBA application will typically require analysts and/or decision-makers to make judgement on the appropriate equity needs of society, both now and in the future. In the context of low probability, high impact events, judgements may also need to be made about appropriate level of societal risk, and the worth of implementing options that while perhaps enhancing resilience to a broad range of risks, will be effective to an unknowable extent. Moreover, these considerations must be balanced against a range of other socio-economic, environmental and cultural implications, often with significant uncertainties.

This brings to the forefront the immense importance of *decision structuring* and *decision delegation* for disaster risk management. Decision structuring tasks include defining the problem in a way that opens it up to thoughtful consideration, defining the objectives sought to be achieved, and assembling the list of options that might achieve those objectives and hence will be subject to evaluation. It is important that policy makers and communities consistently monitor and reevaluate the way in which these processes are undertaken. For example, are the policies guiding decision makers relevant and up to date? How is feedback and learning incorporated into the process of option identification? Also, who has been given the power to make decisions and has their discretion been appropriately guided and constrained? Above all, good research must work hand in hand with good governance to transport current economic evaluation approaches to disaster risk decision-making into an era of resilience.

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