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Review Article
"Valuating the intangible effects of natural hazards – review and analysis of the costing methods"

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Abstract. The "intangible" or "non-market" effects are those costs of natural hazards which are not, or at least not easily measurable in monetary terms, as for example, impacts on health, cultural heritage or the environment. The intangible effects are often not included in costs assessments of natural hazards leading to an incomplete and biased cost assessment. However, several methods exist which try to estimate these effects in a non-monetary or monetary form. The objective of the present paper is to review and evaluate methods for estimating the intangible effects of natural hazards, specifically related to health and environmental effects. Existing methods are analyzed and compared using various criteria, research gaps are identified, application recommendations are provided, and valuation issues that should be addressed by the scientific community are highlighted.

1 Introduction

The current practice of disaster risk assessment mainly focuses on damages that can be easily measured in monetary terms, i.e. the so called "tangible" damages (Smith and Ward, 1998; Penning-Rowsell et al., 2003). More precisely, many damage evaluation approaches applied in different European countries focus on damage to assets, like the physical destruction of buildings and inventories (Meyer and Messner, 2005). Such cost estimations calculate the expected damages or the degree of damage based on the market values of assets (Messner et al., 2007). On the contrary, health effects and damages to environmental goods and services, which are not traded in a market, are far more difficult to assess in monetary terms and often are not included in costs assessments of natural hazards leading to an incomplete and biased cost assessment. These costs are indicated as "intangibles" or "non-market". This paper focuses on the cost-assessment of environmental and health effects of four types of hazards (floods, droughts, coastal and alpine hazards). The main intangible effects of the four selected types of natural hazards are listed in Table 1. These effects are varying for each type natural hazard, depending also on the severity of the events. In regards to the classification of the natural hazards types, we are following the typology described in the ConHaz EU project (www.conhaz.org): floods, droughts, coastal hazards (including coastal floods and storms) and alpine hazards (including landslides, avalanches and floods).

Only few examples exist for an ex-post estimation of the environmental and health costs of natural hazards (see e.g. "Post-Disaster Needs Assessment" of the International Recovery Platform, http://www.recoveryplatform.org/pdna/). But also ex-ante estimations of intangible costs are currently rarely applied (for exceptions see e.g. Turner et al., 1995 or Hartje et al., 2001). On that basis, an optimised allocation and design of damage reduction measures cannot be ensured. Hence, for an integrated risk assessment and management of natural hazards it would be necessary to consider also the intangible impacts and their costs. In this context, several methods exist which can be applied for the estimation of these effects in monetary form.

The objectives of this paper are to compile and analyze methods for the assessment of health and environmental effects caused by natural hazards, to provide recommendations on these methods and to identify research needs and knowledge gaps.

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Table 1. The intangible effects of natural hazards (++: severe damages, +: important damages.

	Intangible costs effects	Types of hazards
Environment	Biodiversity loss	Droughts (++) floods (+)
	Loss of wetlands	Droughts (++)
	Soil contamination	Floods & coastal (++) alpine (+)
	& pollution	Floods (++) coastal (+)
	Water pollution	Droughts (++)
	Water depletion	Droughts (++) floods (+)
	Loss of soil nutrients	Floods (++) droughts, coastal (+)
	Soil erosion	All (minor)
	Aesthetic environment	
	impacts	
Health	Fatalities/injuries	All
	Infectious diseases	Floods (++) coastal (+)
	Mental illnesses	All
	e.g. post-traumatic	Droughts (++) floods (+)
	stress, depression	
	Malnutrition	

Source: Markantonis et al., 2011

In order to achieve these objectives a literature review was carried out to compile the state-of-art of the methods applied for the cost-assessment of intangible effects. Additional input has been provided by four thematic workshops: costs of: (a) floods, (b) droughts, (c) coastal hazards and (d) alpine hazards. The stakeholder workshops were organised along natural hazard types in order to provide a common understanding of cost assessment in the fields of policy, science and practice as well as to identify various views on opportunities and shortcomings of current cost assessment methods.

The paper is structured as follows: In the second part cost-assessment methods of the intangible effects which can be found in literature are presented. In this context, a general theoretical basis for estimating the intangible effects is illustrated and, based on that, cost-assessment methods that are applied or could potentially be applied are described. The review of the cost-assessment methods concerns the four selected natural hazards, for which exemplary applications are provided. The third part evaluates the cost-assessment methods in a qualitative way by providing an analysis and comparison using various criteria. Finally, the fourth part summarizes the most important conclusions concerning the application of different cost-assessment methods used for the estimation of the natural hazards' environmental and health costs. More specifically, this section explores best practices and seeks for knowledge gaps and research questions that should be addressed by the scientific community.

2 Theory and methods estimating the intangible effects of the natural hazards

Most often the cost assessment of natural hazards impacts covers mainly direct and in some cases indirect costs. In contrast, intangible costs are often not considered in current practices (see e.g. Meyer and Messner, 2005). However, it is essential to valuate the intangible effects on human, social and natural capital in order to allocate available resources in a way that provides sustainable well-being (Costanza and Farley, 2007). Intangible effects could be included in decision support frameworks either in a non-monetary form in a multi-criteria analysis framework or in monetary form in a cost-benefit analysis framework. In this paper we will focus on the latter. In order to integrate all intangible effects in such a cost-benefit analysis framework they need to be valued in monetary terms (Pearce and Turner, 1990). Quantification and monetization (for the handling of trade-offs between different functions) of environmental goods and health functions therefore is a basic requirement for sustainability and for economic efficiency of public investment (Markantonis et al., 2011). In this context, the present chapter presents the cost-methods that are used or could potentially be used to valuate the intangible costs (environmental and health) of the selected types of natural hazards.

The cost assessment of intangible effects of natural hazards is following the main principles of welfare economics. One of the central themes in the field of welfare economics is to consider all categories of total economic value in decision-making. This includes also the value of environment or human health. According to welfare economics, individuals derive values from non-market goods, especially environmental and health assets, through many more ways than just

Table 2. Cost-assessment methods estimating the intangible costs of natural hazards.

Revealed Preferences Methods	Stated Preferences Methods
Hedonic Pricing Method (HPM)	Contingent Valuation Method (CVM)
Travel Cost Method (TCM)	Choice Modeling Method (CMM)
Cost of Illness Approach (COI)	Life Satisfaction Analysis (LSA)
Replacement Cost (or restoration cost) Method (RCM)	

Benefit Transfer Method (BTM)

direct consumption (Pearce and Turner, 1990). More specifically, they refer to the importance of considering the Total Economic Value (TEV) of a non-market asset. TEV recognizes two basic distinctions between the value that individuals derive from using environmental goods and services, i.e. use values, and the value that individuals derive from the environmental resource even if they themselves do not use it, i.e. non-use values. In this context, the concept of total economic value (TEV) helps to identify the different market (tangible) and non-market (intangible) values that might be damaged in a natural hazard event (OECD, 2000).

The cost assessment methods for estimating the intangible effects of natural hazards are categorized into revealed preferences and stated preferences methods (Markantonis et al., 2011). The revealed preferences methods, such as avoidance cost and hedonic studies, have the advantage of producing estimates of the value for a particular good from actual market behavior. In contrast, the stated preferences methods (contingent valuation and choice modeling) create a hypothetical or contingent market, and analyze choices. The cost-assessment methods that are analyzed in this report are presented in the Table 2.

The revealed preferences methods look for related markets in which the non-market good is implicitly traded (Lancaster, 1966). The most popular revealed preferences methods are the hedonic pricing and the travel cost methods. In the context of estimating intangible costs of natural hazards, both methods have been applied. For example, Hamilton (2007) uses property prices in Schleswig Holstein to derive estimates of the value people attach to different coastal attributes that are at stake if flood events increase as a result of climate change. In another study (Hartje et al., 2001) the Travel Cost Method is applied to estimate the recreational value of the island of Sylt and the impact of more frequent storm surges on this recreational value. For the valuation of the environmental goods or services also, the replacement cost approach is used and analyzed in the present paper. In Leschine et al. (1997) the Replacement Cost method has been applied to estimate the economic value of wetlands' flood protection capacity in Western Washington. Moreover, another method, considered as revealed preferences one, which has a wide practical implementation concerning the health impacts of natural hazards is the cost of illness approach. The cost of illness was applied in the DEFRA (2007) study to estimate the health costs of the 2007 floods in UK. In this case, health costs were estimated based on working days lost due to ill induced by flooding. Work absences at a national level and average wage rates were the data used for this analysis.

The stated preferences methods have been developed to value environmental goods that are not traded in any related market (Birol et al., 2006). Stated preferences methods are survey-based approaches that elicit people's preference directly by using one of the following measures: willingness to pay (WTP) to obtain an environmental improvement or to avoid an environmental deterioration, or willingness to accept (WTA) compensation for relinquishing an environmental deterioration or to forgo an environmental improvement. The methods bypass the need of a market for environmental assets by presenting individuals with a hypothetical market in which they have the opportunity to buy (WTP) or sell (WTA) the environmental good in question. People's actions are contingent on the hypothetical situation described to them, and elicited WTP and WTA bids are close to the value that would be revealed if an actual market existed (Cummings et al., 1986; Garrod and Willis, 1999; Mitchell and Carson, 1989). The main advantage of stated preferences methods is that they are the only methods capable of estimating both use and non-use values. In general not many studies have been elaborated to estimate intangible costs, but however, the majority of the so far applied case studies are using stated preferences methods for this purpose. Both WTP and WTA measures are an important supplement to the revealed preferences method, since they measure welfare affects of damage and can thus be integrated in cost-benefit decisions (Pearce and Smale, 2005). Typical approaches for estimating the environmental and health goods or services are: (1) Contingent Valuation (CVM), in which respondents are directly asked about their willingness to pay for a certain improvement; (2) Choice Modelling (CM), in which respondents are presented with different bundles of goods at a certain price among which they are asked to make a choice; and (3) Life Satisfaction Analysis which correlates the degree of public goods with individuals' reported subjective well-being and evaluates them directly in terms of life satisfaction.

The above mentioned stated preferences methods have been applied in several cases to estimate the intangible

Table 3. Analysis of the methods for estimating the intangible costs of the natural hazards.

	Scope	Spatial scale	Time scale	Data availability (AV) and quality (QU)	Effort required	Expected precision	Ability to deal with the dynamics of risk	Applied ex-ante or ex-post
Revealed Preferences Methods								
Hedonic Pricing Method (HPM)	Both	Local Regional	Mid-term	AV: Low-High QU: Low-Moderate	Low	Moderate	Low-Moderate	Ex-post
Travel Cost Method (TCM)	Sectoral	Local Regional	Short-term (Mid-term)	AV: Moderate-High QU: Moderate-High	Low-Moderate	Moderate-High	Low-Moderate	Ex-post
Cost of Illness Approach (COI)	Sectoral	Local Regional National	Short-term Mid-term	AV: Moderate-High QU: Moderate-High	Low	Moderate-High	Low-Moderate	Ex-post
Replacement Cost Method (RCM)	Sectoral	Local Regional National	Short-term (Mid-term)	AV: Moderate QU: Moderate	Low	Moderate-High	Low-Moderate	Ex-post
Stated Preferences Methods								
Contingent Valuation Method (CVM)	Both	Local Regional National (GLOBAL)	Short-term Mid-term Long-term (Very long)	AV: Moderate-High QU: Low	Moderate-High	Low-High	Moderate-High	Ex-ante and Ex-post
Choice Modelling Method (CMM)	Both	Local Regional National (GLOBAL)	Short-term Mid-term Long-term (Very long)	AV: Moderate-High QU: Low	Moderate-High	Low-High	Moderate-High	Ex-ante and Ex-post
Life Satisfaction Analysis (LSA)	Both	Local Regional National (GLOBAL)	Short-term Mid-term Long-term (Very long)	AV: Moderate-High QU: Low	Moderate-High	Low-High	Moderate-High	Ex-ante and Ex-post
Benefit Transfer Method (BTM)	Both	Local Regional	Short-term Mid-term Long-term	AV: High QU: Moderate	Low-Moderate	Low-Moderate	Moderate	Ex-post

effects of natural hazards. Messner et al. (2007) presents some examples for applications of CVM, describes how monetization of environmental goods can be accomplished and – based mainly on Arrow et al. (1993) – gives some recommendations on how CVM techniques should be applied. Daun and Clark (2000) are using a CVM to estimate the WTP for the maintenance of status quo flooding risk levels and/or corresponding ecological improvements to the watersheds. In the study by Birol et al. (2006) a CVM valuation survey has been used to estimate the non-use values affected by the droughts of the Cheimaditida wetland in Greece. Hensher et al. (2006) apply choice experiments in Canberra, Australia in order to estimate households' and businesses' willingness to pay (WTP) to avoid drought water restrictions. Finally, in the study of Carroll et al. (2009) a fixed-effects model for Australia matching rainfall data with individual life satisfaction was used to estimate the total cost of the 2002 drought, the costs of drought among residents in rural and urban areas and the potential costs of a doubling in the frequency of spring droughts.

Additionally, the benefit-transfer method is based on transferring results of previously applied stated or revealed preferences methods to other study areas in order to valuate the intangible costs. For example, Martin-Ortega and Markandya (2009) apply the benefit transfer approach, based on public's willingness to pay for the estimation of the environmental costs of drought events, through a value transfer exercise. The estimates for the valuation of the droughts' environmental costs in this case were transferred from a choice experiment that was applied by the AquaMoney project (www.aquamoney.org) in four river basins in Southern Europe.

However, a strong debate emerges in welfare economics related to the shortcomings and the constraints of the revealed and stated preferences methods. A usual problem of these methods is that they are ignoring the income constraints and hence providing biased values (Bithas, 2011). Additionally, the valuation of environmental and health goods are constrained by the unavoidable presence of the "time span effect" and the "spatial range effect" (Bithas, 2006). The time span effect describes the time horizon within which individuals make monetary valuation while the spatial range effect defines the space within which the individuals perceive this welfare (Bithas, 2011). In this context, the valuation methods cannot precisely estimate environmental and health effects of natural hazards that are spread in a long term period and in a large spatial scale. A step further, the valuation of the environmental assets and functions is not even required in a policy framework that sets purely ecological targets (Bromley, 1998). Furthermore, specifically regarding stated preferences methods, there is a range of conceptual, empirical and practical issues that are associated with monetary estimations of economic values based on hypothetical markets. A constant debate in literature addresses the shortcomings of stated preferences methods concerning possible biases, protest bids, free-riders, etc (Carson, 2001). The disadvantages of stated preferences methods can be summarized as following (CGER, 1997): (a) Subject to various biases (e.g. interviewing bias, starting point bias, non-response bias, strategic bias, yea-saying bias, insensitivity to scope or embedding bias, payment vehicle bias, information bias, hypothetical bias), (b) Expensive due to the need for thorough survey development and pre-testing, (c) Controversial for non-use value applications.

An analytical comparison of the cost-assessment methods, used exclusively for valuing the intangible effects of natural hazards, is provided in Sect. 3 of this paper.

3 Analysis of the cost-assessment methods

Following the presentation of the cost-assessment methods this section aims to analyze the cost-assessment methods in a qualitative way. The comparison of the various cost-assessment methods is achieved by using the following criteria:

1. Scope. This criterion regards the comprehensiveness of the methods in the decision making system and examines if the method deals with certain types of costs or if it provides a comprehensive approach. Gradation: 1: "Sectoral", 2: "Intersectoral", 3: "Both"

2. Spatial scale. The spatial implementation dimension of the methods is analyzed under this criterion. Gradation: (1: "local", 2: "regional", 3: "national", 4: "global")

3. Time scale. Likely the spatial scale, the time scale is also analyzed concerning the time period that each method is covering when applied. Gradation: (1: "short-term (on the spot)", 2: "mid-term (<3 yr)", 3: "long term (3–50 yr)", 4: "Very long-term (>50 yr)")

4. Data availability and quality. This criterion concerns the availability and the quality assurance of the data necessary for the application of each cost-assessment method. Gradation: (1: "low", 2: "moderate", 3: "high")

5. Effort required. The financial and the human resources that are demanded for the application of each method are compared under this criterion. Gradation: (1: "low", 2: "moderate", 3: "high")

6. Expected precision. It describes the precision of the results produced. Gradation: (1: "low", 2: "moderate", 3: "high")

7. Ability to deal with the dynamics of risk. This criterion deals with the ability of the methods to deal with the dynamics of risks and to be implemented in future risk scenarios, mainly linked to climate change. Gradation: (1: "low", 2: "moderate", 3: "high")

8. Applied ex-ante or ex-post: It deals with the ability of the methods to be applied ex-ante in a hypothetical or laboratory setting or ex-post based on market observations. Gradation: (1: "ex-ante", 2: "ex-post", 3 : "ex-ante and ex-post")

By using these criteria to evaluate the various methods we aim to provide a tool for decision makers and practitioners that would assist them to select the most appropriate method or methods for their specific case study. Each criterion is evaluated in a qualitative scale of predefined graded answers. The judgment for weighting each method under their criteria is based on an extensive state-of-the-art review as well as on the outcome of the four hazard specific expert workshops. During the workshops scientists, decision-makers and practitioners discussed, analyzed and evaluated the application different cost-assessment methods, including those for estimating intangible effects. The comparison and analysis of the cost assessment methods are presented in the Table 3.

4 Findings, recommendations and further discussion

This section presents the most important conclusions and recommendations concerning the application of different cost-assessment methods used for the estimation of the natural hazards' intangible costs. More specifically, we explore the best practice approaches, identify which methods assure the highest quality of the produced cost estimations, identify the potential for knowledge transfer between the different hazard communities and seek for knowledge gaps that should be addressed by the scientific community.

4.1 Findings

Regarding the evaluation of the methods in general, there is no "good" or "bad" practice. Depending on the characteristics of each case-study scientists and decision-makers can select the method or methods that correspond better or even not to monetize at all the intangible effects. The accuracy of the cost-assessment methods depend on the data availability and quality, the available resources and the decision made in each case in order to select the most appropriate method for estimating the intangible effects. While revealed preferences methods provide more precise and reliable results compared to the stated preferences methods (see Table 3), there are serious distortions in the markets in reflecting the risk of natural hazards (e.g. missing signals, owner-tenant-relationships, etc.). Revealed preferences techniques, furthermore, require less financial and human resources compared to stated preference methods (see Table 3). In practice, stated preference methods are the most common in valuing intangible effects because they can estimate both use and non-use values. Stated preference techniques can be also used for long-term and global effects but are more uncertain under these conditions compared to applications for local and short-term cost-estimations (see Table 3). Theoretically when estimating intangible impacts at large areas and for longer time frameworks, revealed preferences methods are more precise and effective. However, in practice many difficulties occur when applying revealed preferences methods, which are mainly related to the availability and the validity of data.

Since the environmental and health effects of natural hazards regard use and non-use values, stated preferences methods are very important in order to estimate the natural hazards intangible costs. Among the stated preferences methods, the Contingent Valuation Method (CVM) is the most commonly applied technique for the estimation of intangible costs. It is already quite established and highly standardized. More recently, CMM has become more popular due to several advantages compared to CVM. These include the ease of estimating values of single attributes of an environmental resource, avoidance of part-whole bias problem since different levels of the good can be easily built into the experimental design and avoidance of yeah-saying in the case of double-bounded dichotomous choice in CVM. However, there are also some drawbacks to CMM. It is much more demanding for respondents to answer, preferences may be inconsistent throughout the experiment, the design of a CMM experiment needs to be well elaborated and its incentive properties are unclear. The Benefit-Transfer method can be an alternative if only few resources are available and the demand for precision is relatively low (see Table 3). In this case, valuation studies with very similar characteristics should be used and the adjustment to the needs of the new case-study should be done precisely.

The various uncertainties in estimating the costs of intangible effects are an important problem. Uncertainties emerge due do their incomplete definition and the absence of market prices. A strong uncertainty factor is the lack of knowledge on the physical impacts and lack of experience in estimating intangible effects, which should be the basis for a sound estimation of the monetary costs. More specific, only a few studies have been elaborated to define the environmental impacts of natural hazards (e.g. Euripidou and Murray, 2004; EEA, 2001; EC, 2008; Brown et al., 2007). Likely, only some epidemiological studies have been elaborated towards defining the health impacts of natural hazards (e.g. Adis and Junk, 2002; Ebi, 2006; EEA, 2010; TC-CCR, 2004; Few et al., 2004; Jakubika et al., 2010). Out of the four natural hazards types considered, the most experiences regarding cost-assessment of intangible effects have been gathered in the context of floods. On the contrary, the assessment of environmental effects is largely missing in the case of natural disaster risk management in the field of the alpine hazards. Cost-estimations are often fragmented, and are not integrated into planning procedures and integrated decision support frameworks like cost-benefit analysis or multicriteria analysis. Another uncertainty factor is often the low quality and quantity of the available data. Data for revealed preferences methods is usually derived ex-post to the natural hazard event. Data quality is usually quite good as it is based on real market prices and socio-economic data. On the contrary, data for stated preferences methods can be derived both ex-post and ex-ante, but the quality depends on how the experience is when applying these methods for such specific environmental and health assests. The more knowledge we gain when applying cost-assessment methods, the more we decrease uncertainly factors related to methodological problems (e.g. biases, formulation of valuation scenarios, double-counting) that often occur when applying these approaches.

4.2 Recommendations and further discussion

With regard to recommendations and challenges for future research, what initially emerges is a need for systematic definition and estimation of the physical impacts of the natural hazards on human health and the environment. In this context, there seems to be a need for a closer cooperation of health scientists, ecologists and economists in order to better identify, quantify and evaluate the intangible effects caused by floods, droughts, coastal and the alpine hazards. Another important scientific challenge of the cost-assessment process would be the intense exploration of the dynamics of risks in systems under the threat of climate and socio-economic change, since the current cost-assessment approaches are mainly valuating the short term impacts of the intangible effects. Additionally, to human health and environmental effects, more intangible effects may occur related to social distribution issues, like the disruption of the social cohesion in an affected area and cultural heritage impacts. Within this framework social scientists can also contribute to a more efficient estimation of the intangible impacts. A systemic approach which tries to integrate all the different types of intangible effects is needed.

A better communication of the "intangibles" best-practices including gained knowledge about effects, costs and valuation methods is essential in a context of knowledge exchange. The first step towards more intense knowledge transfer between the hazard communities would be to develop a common terminology and definition of the various health and environmental impacts, providing this way a commonly accepted scientific basis. In this case, a common definition and terminology of the intangible costs prerequisites a close cooperation and knowledge transfer among the different hazards communities. The development of large scale and open-access databases would also facilitate the knowledge transfer among the different hazard communities. Furthermore, in providing an integrated cost-assessment of the intangible effects, scientists from various disciplines (ecologists, economists, health practitioners etc) and expertise in different natural hazards should establish those dialogue and collaboration structures that will enable knowledge transfer and learning capacity.

Regarding specific methods, stated preferences methods should be applied systematically in order to achieve more accurate results. In this context it is recommended that the surveys should be applied in repeated time periods and under similar contexts, this way eliminating the various biases. Revealed preferences should use long time and verified data series in order to eliminate market price distortions, caused by other sources than natural hazards, and hence to provide more accurate results. Due to the complexity and uncertainty of the intangible effects, a combination of relevant methods could help to unveil differences in the valuation approaches and help to enhance the accuracy of the results. In this context, stated preferences and revealed preferences methods should be applied in parallel and complementary. However, such an option demands increased resources.

Finally, more research could be undertaken in order to find ways to better integrate the results of aforementioned stated or revealed preferences methods into decision support methods like cost-benefit analysis or multicriteria analysis as well as to incorporate cost estimations in wider risk management plans.

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