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THE IMPACT OF DEBIASING ON UNCERTAINTY COMMUNICATION

AN APPLICATION TO MULTI-CRITERIA DECISION ANALYSIS IN THE AREA OF CLIMATE CHANGE

WORKING PAPER, 2017

ABOUT THIS DOCUMENT

Daniel Puig and Fatemeh Bakhtiari (Technical University of Denmark) researched and wrote this working paper. Initially, the text was drafted as a 'supplementary information' note to a manuscript submitted to a peer-reviewed journal. As part of the review process, that note (i.e. the text that makes up this working paper) benefited from detailed comments by three anonymous reviewers. Subsequently, the manuscript was re-written, making the 'supplementary information' note unnecessary. For this reason, we are publishing the text in that note (incorporating the review comments) as a working paper.

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FOREWORD

This working paper explores the extent to which uncertainty characterisation and reduction (debiasing) may affect uncertainty communication. To do so, we examine whether the application of a set of debiasing techniques facilitates or hinders the process of obtaining the information required in an uncertainty communication protocol. We focus on two policy prioritisation processes in the area of climate-change policy planning, both of which relied on multi-criteria decision analysis. The paper highlights the trade-offs associated with both processes – characterising and reducing uncertainty, and communicating uncertainty – and provides pointers about potential future research in this area.

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1. INTRODUCTION

Over the years, decision theory has developed analytical frameworks to aid decision-making, among which a few focus explicitly on the treatment of uncertainty (Raiffa 1968). Application of these frameworks has shown that the risk associated with decision-making under uncertainty is an inherently subjective concept, about which different individuals will have different perceptions (Morgan 2002 ; Etkin and Ho 2007 ; Smith and Joffe 2009 ; Whitmarsh 2008). In light of this the need for collaborative processes, whereby scientists and decision-makers educate one another about their respective needs and capabilities, becomes self-evident (Fischhoff and Scheufele 2014). Regrettably, communication between scientists and decision-makers is limited: science is not easily accessible to decision-makers, and scientists often fail to understand decision-makers' information needs (von Winterfeldt 2013).

Efforts to characterise and reduce uncertainty typically result in an expanded, more nuanced evidence base (Morgan 2009). By virtue of this, such efforts may make uncertainty communication more challenging (Fischhoff 2013). When this is so, uncertainty characterisation and reduction defeats its own purpose, at least from the viewpoint of the role that uncertainty characterisation and reduction must play in supporting robust decision-making.

A growing body of research focuses on uncertainty characterisation and reduction. The subset of this literature that is relevant to climate-change policy analysis explores three main issues. A first set of issues relates to analytical methods that can be applied in a variety of decision-making contexts. These include, for example, advances on techniques such as Monte Carlo simulations, or expert judgement elicitation (Hart *et al.* 2014 ; Morgan 2009 ; Spiegehalter 2011). A second set of issues relates to applications of the above methods, mostly in situations of limited uncertainty. This includes, for example, assessments in sectors such as energy or forestry (Oppenheimer *et al.* 2016 ; Thompson and Calkin 2011; Webster *et al.* 2010). A third set of issues relates to exploratory work concerning so-called deep uncertainty, a type of especially pervasive uncertainty. This includes, for example, descriptions of quantitative tools, such as robust decision making, or info-gap methods (Hall *et al.* 2012 ; Kasperson *et al.* 2008; Weitzman 2014). Limited research has been conducted on uncertainty characterisation and reduction in the context of a specific decision-support tool. Targeting one particular decision-support tool (multi-criteria decision analysis), Montibeller and von Winterfeldt (2015) suggest a number of debiasing techniques, the use of which could reduce uncertainty and, thereby, increase "the quality of the analysis".

Conversely, uncertainty communication has been researched less. Morgan (2002) formalises the concept of 'mental models', a framework for identifying the main issues that need correcting or communicating (by scientists, to decision makers). Noting the difficulties associated with communicating uncertainties expressed as probabilities, especially with regard to lay audiences, Spiegelhalter and colleagues (2011) examine practices for communicating uncertainties visually. Fischhoff and Davis (2014) propose a protocol that is structured around a set of six determinants of uncertainty (Table 1), with the objective of systematising the dialogue between scientists, and the decision-makers who need to understand the uncertainties associated with a particular scientific result. While none of this research efforts focuses on a particular sector or societal challenge, the findings are applicable across most, including climate change.

Table 1: The Fischhoff and Davis protocol for uncertainty communication

Steps	Actions
1	Identify key outcomes for decision-makers and how to measure them
2	Summarise variability
3	Summarise internal validity (i.e. attrition bias, administration, performance bias)
4	Summarise external validity (i.e. population bias, intervention bias, control group bias, scenario bias)
5	Summarise the strength of the basic science (i.e. directness, empirical basis, methodological rigor, validation)
6	Summarise uncertainty

Source: Fischhoff and Davis (2014)

In what situations, and to what extent, uncertainty communication is hampered by uncertainty characterisation and reduction has not been studied. A better understanding of the interplay between uncertainty characterisation and reduction, and uncertainty communication, has the potential to increase the effectiveness of both types of efforts. In areas like climate change, where uncertainty is central to the analysis that underpins the policy process, such improved understanding could foster more effective and efficient climate change policies.

This working paper explores the impact that a number of debiasing techniques may have with regard to communicating the uncertainty associated with the outputs of two applications of multi-criteria decision analysis. [1] This work sheds some light on two under-researched issues. Firstly, the type of impact, positive or negative, that different debiasing techniques are likely to have with regard to uncertainty communication. Secondly, the aspects of uncertainty communication (for example, summarise variability, or summarise internal validity, among others) that are likely to be most affected. The results presented in this working paper underscore the need to introduce explicit uncertainty communication provisions in analyses aimed to inform climate-change policy decisions.

The remainder of the working paper is structured around four sections. Section 2 introduces the two case studies from which data are drawn. To facilitate the subsequent analysis, the scope of each case study is described against each of the six steps in the Fischhoff and Davis protocol for uncertainty communication (Table 1). Section 3 synthesises the results of a post-hoc application of the protocol to the two case studies introduced in section 2. [2] For each of the two case studies, section 4 analyses the impact that characterising and reducing uncertainty might have with regard to communicating uncertainty. Section 5 concludes by (i) discussing the aspects of multi-criteria decision analysis for which uncertainty communication may be more challenging, and (ii) giving pointers about potential future research topics with regard to debiasing tools.

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[1] *Debiasing refers to eliminating biases that introduce uncertainty in the analysis. The study of biases goes back at least four decades (Tversky and Kahneman 1975). It has resulted in a number of detailed characterisations, which underpin debiasing techniques such as that by Montibeller and von Winterfeldt. Debiasing helps reduce uncertainty, thus contributing to more useful analyses in support of public policy.*

[2] *Post-hoc assessment refers to an assessment that is conducted after the main analysis has been completed, with a view to studying an aspect of the system that the main analysis did not study (in this case, the impact of debiasing on uncertainty communication).*

2. TWO NATIONAL-LEVEL CLIMATE-CHANGE PLANNING PROCESSES

The conclusions derived in this working paper are based on two national-level climate-change planning processes. These processes share one feature: multi-criteria decision analysis is the decision-support tool around which the planning process is articulated.

Multi-criteria decision analysis has been hailed as particularly well suited for decisions involving diverse stakeholders, multiple and conflicting objectives, and uncertainty (Belton and Stewart 2010 ; UNEP 2011). [3] An annex (Annex 1) outlines the basic tenets of multi-criteria decision analysis.

Hereinafter the two planning processes referred to above are labelled, respectively, 'technology needs assessment' programme and 'adaptation priorities in Mexico' programme. Two annexes (Annex 2 and Annex 3) provide additional background on each of the programmes.

The 'technology needs assessment' programme is sponsored by the United Nations Framework Convention on Climate Change. Targeting developing countries, its objective is to arrive at an official, prioritised list of mitigation and adaptation technology needs at the national level, agreed upon by all relevant governmental agencies. The associated prioritisation process relies on multi-criteria decision analysis (specifically, the 'technology needs assessment' programme uses the multi-criteria decision analysis method commonly known as linear additive modelling).

The 'adaptation priorities in Mexico' programme was sponsored by the Mexican Ministry of Environment and Natural Resources. The goal of the programme was twofold: contribute to the identification of priorities for inclusion in the national climate change strategy, and provide a tool for prioritising applications submitted to the board of the national climate change fund. [4] The programme relied on multi-criteria decision analysis to guide both types of prioritisations (specifically, the 'adaptation priorities in Mexico' programme used the method known as multi-attribute utility theory).

The following paragraphs are organised around six sections, one for each of the 'steps' in the Fischhoff and Davis protocol for uncertainty communication (Table 1). Each section provides a brief account of the extent to which, in each of the two programmes considered, the requirements inherent to the various 'steps' in the protocol were met.

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[3] *The literature on multi-criteria decision analysis applied to climate change policy making is summarised in two documents: a report on a two-year effort that sought to develop a generalizable approach (UNEP 2011), and a special issue published in Mitigation and Adaptation Strategies for Global Change (see notably Scrieciu et al. 2014). The latter concluded that multi-criteria decision analysis possibly represents the most appropriate decision-support tool when it comes to policy prioritisation for climate change at the national and sub-national levels. This includes situations in which uncertainty is high, as is the case in adaptation to climate change, but excludes 'deep uncertainty'.*

A focus on uncertainty is only found in the subset of the literature that explores multi-criteria decision analysis as a tool (that is, without any specific focus on climate change). For example, Cinelli and colleagues (2014) analyse the extent to which a given approach to multi-criteria decision analysis can aptly incorporate uncertainty quantifications, whereas Durbach and Stewart (2012) focus on the range of tools that can be used, alongside multi-criteria decision analysis techniques, to quantify relevant uncertainties. Among these, Monte Carlo simulations have received most attention (Madani and Lund 2011).

[4] *Three sectors were targeted: forests and land use management, water management, and irrigated agriculture. Of these three sectors, the irrigated agriculture sector was subject to the most comprehensive prioritisation process. This working paper only considers irrigated agriculture.*

STEP 1: IDENTIFY KEY OUTCOMES AND HOW TO MEASURE THEM

Reducing national greenhouse-gas emissions is the overarching expected outcome of the climate change mitigation component in the ‘technology needs assessment’ programme. Internationally accepted ‘good practice’ protocols exist that governments can use to measure greenhouse-gas emissions (IPCC 2006). However, because the programme itself is not linked to a specific emission reductions target, the actual outcome of the programme cannot be quantified in terms of greenhouse-gas levels abated: any amount of emission reductions can be construed to be a satisfactory outcome. Senior policy-makers were aware of this ambiguity.

Promoting adaptation to climate change is the overarching expected outcome of both the adaptation component in the ‘technology needs assessment’ programme, and the two components in the Mexican programme (prioritisation of policies, and prioritisation of applications submitted to the fund). Measuring progress with adaptation is particularly challenging, as climate change impacts vary from one location to another, and with time. Due to their country-wide scope, neither the ‘technology needs assessment’ programme, nor the policy prioritisation component of the Mexican programme could measure with any accuracy climate-change adaptation outcomes, a shortcoming that was clear to senior policy-makers. This could be possible in the case of the ‘climate change fund’ component of the Mexican programme because, by design, it intends to support projects that can measure outcomes more accurately. [5]

STEP 2 SUMMARISE VARIABILITY

In both its mitigation and adaptation components, the ‘technology needs assessment’ programme took variability into consideration in very few instances only, and mainly with regard to the assumptions concerning unit costs (for example, the average cost of generating one kWh of electricity). This was done by expressing unit-cost estimates as ranges, to signal that actual costs depend on a number of hard-to-predict parameters, such as technology maintenance costs. To an even lesser extent variability was reflected in the assumptions about emissions of greenhouse gases per unit of output (be it industrial production, or distance travelled, for example). [6] Similarly, with regard to adaptation, variability was rarely reflected in the analysis, and only in a very crude manner (for example, through sector-specific assumptions about vulnerability to the impacts of climate change). This level of detail failed to reach senior policy-makers, who focused on the final ranking of technologies.

Given its breadth, the Mexican programme did not take variability into consideration. This is because, to accommodate such broad scope, most indicators were defined in terms of the extent to which implementing a given option would represent a departure from the prevailing situation. For example, for options involving new technologies, the cost implications of these options were characterised through the cost increment that they entailed, compared to the cost of traditional technologies. While this set up could in principle have reflected variability, in the end it did not, to avoid introducing additional analytical complexity. Senior policy-makers were not made aware of this shortcoming, which was perceived as a technical detail unworthy of their time.

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[5] *Compared to the policy prioritisation component of the programme, the component aimed at prioritising applications for the fund dealt with shorter time frames and narrower issues (that is, specific immediate interventions, in one or a small number of locations in Mexico). This is the main reason why this component could measure outcomes far more accurately.*

[6] *This was achieved by using a range of possible emissions factors, instead of one single ‘best estimate’.*

STEP 3 SUMMARISE INTERNAL VALIDITY

Internal variability can be characterised through four main determinants: selection bias, attrition bias, administration, and performance bias. The following paragraphs discuss each of these determinants separately.

STEP 3.1 | SELECTION BIAS

In some countries, the 'technology needs assessment' programme suffered from selection bias, in that certain sectors were excluded from the outset. For example, adaptation in sectors such as biodiversity was considered too intractable and, for this reason, the sector was not considered at all. The same could be said about expensive climate change mitigation options, such as carbon-dioxide capture and storage. While this can be a perfectly legitimate public policy choice, from a purely scientific perspective the omission represents a bias. These decisions were taken by senior technical staff in government agencies. Senior policy-makers were made aware of the omissions, and endorsed them.

Selection bias was unlikely to affect the 'climate change fund' component of the Mexican programme, since eligibility was defined in very broad terms. With regard to the policy prioritisation component of the Mexican programme, some options were excluded from the outset, further to the results of earlier analyses. For example, unlike irrigated agriculture, non-irrigated agriculture was not targeted. Senior technical staff in government agencies took responsibility for these decisions, which sought to support policy prioritisation (by narrowing down the number of potential target sectors). Senior policy-makers were made aware of the omissions, and endorsed them. In sum, any omissions were introduced by design, and were both explicit and reasoned. Therefore, from the point of view of the programme's final design, the policy prioritisation component of the Mexican programme was unlikely to suffer from selection bias.

STEP 3.2 | ATTRITION BIAS

Although data were scarce, particularly with regard to technologies for adaptation to climate change, the 'technology needs assessment' programme did not suffer from attrition bias: at the end of the prioritisation process the selection of sectors retained coincided with the initial set. [7] The lack of attrition bias was clear to senior policy-makers, who were presented with both the initial set of options, and the final, prioritised set.

Attrition bias was unlikely to affect the Mexican programme. While candidate policies might not have been retained for prioritisation, and candidate projects might not have been retained for funding, it is unlikely that any would have been dropped during the multi-criteria decision analysis process. This is because only highly appropriate policies and projects were pre-selected, further to a range of screening procedures. As above, senior policy-makers in Mexico endorsed these decisions. Because of this, it can be said that the Mexican programme was unlikely to suffer from attrition bias.

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[7] *'Attrition bias' refers to a distortion in the operation of a programme, which results in some of the cases considered initially to be unjustifiably abandoned. It is a type of selection bias in the sense that it detracts the analysis from legitimate cases, thereby distorting the results.*

STEP 3.3 | ADMINISTRATION

In all cases, the 'technology needs assessment' programme was conducted as intended, which in certain countries was a reason for pride. [8] Senior policy-makers were aware of it because, through their commitment with the Global Environment Facility, the funding entity, national governments had engaged in meeting programme requirements, and performance was regularly monitored.

With regard to the Mexican programme, it was suggested that, given the complexity of the indicators proposed (see also 'performance bias', below), a certification programme should have been set up, to ensure that the individuals charged with conducting the multi-criteria decision analysis fully understood that complexity. The setting up of such a certification programme was not seen as realistic option, due to the high costs associated with it. While senior-policy makers were aware of the complexity of the indicators proposed, whether or not they would have received enough information to judge how well the analysis might have been performed, is unclear.

STEP 3.4 | PERFORMANCE BIAS

In some countries, some sectors perceived the 'technology needs assessment' programme as an opportunity to raise interest in, and investment for, the sector. As a result, stakeholders from those sectors engaged more intensely in the programme, compared to their counterparts in other sectors. This may have introduced performance biases in the analyses, in the sense of indirectly (but unduly) promoting certain sectors. The extent to which senior policy-makers may have been aware of this bias is unclear.

The Mexican programme might have suffered from performance bias, because the indicators were rather elaborated. A typical indicator was expressed as a function of different parameters, notably geographic region, type of adaptation measure, and type of crop. For example, the same type of measure (say, a technology upgrade) in the same geographic region (say, Yucatán), may score differently depending on the type of crop considered (say, watermelon versus cucumber). This is because the methods of assessment for each indicator take into consideration such high level of detail. While this granularity would most likely have contributed to improving the analysis, it might have also introduced performance biases. The reason for this is that several analysts would have been needed to complete one scoring process, since no single analyst could possess all the required knowledge, given the large number of crops, types of measures, and regions considered. Besides, from one scoring process to the next, analyst teams would most likely have changed. Having different analysts involved would probably have introduced inconsistencies in the analysis and, therefore, performance biases too. Whether senior policy-makers would have been aware of this is unclear.

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[8] *Two countries voluntarily dropped out, due to domestic political unrest. The rest of the countries successfully delivered all expected outputs.*

STEP 4 SUMMARISE EXTERNAL VALIDITY

The two applications analysed are not affected by 'external variability' issues. This is because, in these applications, there is no difference between the population analysed, and the population of interest: they are effectively the same. [9]

STEP 5 SUMMARISE THE STRENGTHS OF THE BASIC SCIENCE

The strengths of the basic science can be characterised through four main determinants: directness, empirical basis, methodological rigor and validation. The following paragraphs discuss each of these determinants separately.

STEP 5.1 | DIRECTNESS

In both the 'technology needs assessment' and the Mexican programmes, key outcomes are measured indirectly: since the actual performance of a measure cannot be known with accuracy ex-ante, ex-post performance assessments (measurements, in the case of mitigation, and forecasts, in the case of adaptation) applied in comparable situations are used as proxy measures. This is common in most planning efforts related to climate change. In both cases senior-policy makers are aware of it.

STEP 5.2 | EMPIRICAL BASIS

With regard to technologies to mitigate climate change, the 'technology needs assessment' programme relied on well-established evidence. However, regarding technologies for adaptation to climate change, the amount and quality of the evidence available was limited, as is generally the case with adaptation. While none of the national teams attempted to conceal this challenge, few acknowledged it explicitly. Senior policy-makers with a higher level of knowledge about adaptation to climate change were aware of the limitations of the analysis. However, this is unlikely to have been the case among their less knowledgeable counterparts.

The Mexican programme relied on a model that was calibrated using a relatively small number of well-researched studies. The extent to which the conclusions from these studies are valid across the different types of crops and geographic areas considered is not known. This shortcoming compounds to the more generic lack of information concerning the short- and mid-term impacts of climate change, thus introducing uncertainty in the assessment. Whether senior policy-makers would have been made aware of this is unclear.

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[9] *'External variability' would be an issue in, for example, epidemiology studies, where the results obtained through the population under study have to be applied to the (usually much broader) population of interest.*

STEP 5.3 | METHODOLOGICAL RIGOR

The ‘technology needs assessment’ programme relied on a simplified approach to multi-criteria decision analysis: for example, few countries conducted sensitivity analyses, and none calibrated the multi-criteria model that emerged from the stakeholder consultations. In addition, the analytical methods underlying the technology prioritisation process (notably the elaboration of both baseline and policy scenarios) often were rudimentary. This was justifiable from the point of view of the limited resources available in most of the participating countries. Yet, it is possible that, in some countries, the outcome of the work might have changed, should state-of-art approaches have been used. In most instances, senior policy-makers were not made aware of this.

The Mexican programme used a state-of-art approach to multi-criteria decision analysis. Significant efforts went into both running sensitivity analyses and calibrating the model by means of well-researched studies. Similarly, every effort was made to use well-established methods to underpin the prioritisation process (including, for example, impact and risk assessment tools applied to the irrigated agriculture sector). While senior policy-makers did not master the particulars of the approach, they valued (and indeed requested) that such an advanced approach is used.

STEP 5.4 | VALIDATION

The vast majority of the technologies prioritised in the ‘technology needs assessment’ programme have been tried and tested in relevant contexts (either in the same country or in a country with similar levels of development). This was an important pre-condition for senior policy-makers signing off on the final list of priorities, as they were reluctant to entertain options that might prove overly costly or might underperform.

The policy prioritisation component of the Mexican programme relied on well-established options, identified through earlier, purpose-developed studies. Within those options, variations were to be considered (and prioritised using multi-criteria decision analysis). The ‘climate change fund’ component of the Mexican programme was less restrictive, in the sense that, in principle, it might have considered less well-established options. How those options might have fared in the prioritisation process could not be judged ex-ante. Senior policy-makers introduced these requirements in the design of the programme, and thus were fully aware of them.

STEP 6 SUMMARISE UNCERTAINTY

Neither the ‘technology needs assessment’ programme, nor the Mexican programme attempted to explicitly summarise uncertainty. Analyses resulting in binary recommendations are more amenable to summarising uncertainty through, for example, statements of the analysts’ level of confidence in the recommendation. Conversely, formulating such synthetic summarises of uncertainty in the context of what effectively are politically-driven processes is much more challenging, in that subjective choices (notably the relative weights given to the different criteria) play as big a role in the final outcome as other, purely objective determinants. No demands for such summaries came from senior policy-makers.

3. A POST-HOC ASSESSMENT OF UNCERTAINTY COMMUNICATION

This section assesses the extent to which the information needed to communicate uncertainty (to the decision-makers who commissioned the analysis) was produced, as a part of the multi-criteria decision analysis conducted in the two programmes introduced in the previous section. [10] To do this, the protocol for uncertainty communication developed by Fischhoff and Davis is applied.

Each of the six steps in the protocol refers to a set of analytical tasks, the completion of which is a pre-condition for uncertainty communication. For each step in the protocol, this section assesses the extent to which (i) the required analysis was undertaken, and (ii) the implications of the results of the analysis were understood by decision makers.[11]

Findings are summarised in Table 2. Salient aspects of the assessment include:

- When it comes to reduce 'attrition biases' and 'summarise external variability', the required analysis was undertaken, and decision makers were made aware of the implications of the results of the analysis. That this happened in all instances, even though neither of the programmes explicitly sought to communicate uncertainty, is indicative: it suggests that, with regard to reducing attrition biases and summarising external variability, the information needed to do so may be produced as a part of the regular procedures associated with the implementation of a governmental prioritisation programme structured around multi-criteria decision analysis.
- Conversely, when it comes to 'summarise variability' and 'summarise uncertainty', the required analysis was not undertaken. As a result, policy makers were not made aware of the extent to which this represented a gap in knowledge, or the implications of it with regard to the overall conclusions of the analysis. This suggests that, with regard to summarising variability and summarising uncertainty, the information needed to do so is unlikely to be produced as part of the regular implementation of a governmental prioritisation process structured around multi-criteria decision analysis, unless explicit uncertainty communication provisions are included in the programme. While this is not surprising with regard to 'summarise uncertainty', it highlights an element ('summarise variability') which may require special attention from an uncertainty communication viewpoint.
- Compared to the programme 'adaptation priorities in Mexico', the programme 'technology needs assessment' relied on a simpler approach to multi-criteria decision analysis. This may explain the differences that can be observed across programmes with regard to 'administration' and 'methodological rigour': while administering the 'technology needs assessment' programme was comparatively easier, its methodological rigour was comparatively lower (and not high enough to meet the requirements of the uncertainty communication protocol). This suggests not only a trade-off between administration ease and methodological thoroughness, but also the need to ensure minimum quality standards with regard to the latter.

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[10] Through the course of the original multi-criteria decision analysis, some uncertainties were assessed, notably related to assumptions about costs and, in the case of the 'adaptation priorities in Mexico' programme, about future vulnerability levels. These assessments relied on commonly applied techniques, such as sensitivity analyses or multi-model climate projections. Uncertainties were communicated to decision makers, albeit indirectly, as part of larger reports on progress with the multi-criteria decision analysis. Stated differently, uncertainty communication was not an explicit goal of either of the programmes.

[11] The authors are in a position to make this assessment because they have been involved in the multi-criteria decision analyses conducted in the two programmes above.

Table 2: Summary results of a post-hoc assessment of uncertainty communication in two applications of multi-criteria decision analysis

Steps in the Fischhoff and Davis protocol for uncertainty communication	**‘Technology needs assessment’ programme**		**‘Adaptation priorities in Mexico’ programme**	
	Mitigation	**Adaptation**	**Prioritisation**	**Fund**
1. Identify key outcomes and how to measure them	N / A	N / A	N / A	Y / A
2. Summarise variability	N / U	N / U	N / U	N / U
3. Summarise internal validity				
3.1 Selection biases	N / A	N / A	N / A	Y / A
3.2 Attrition biases	Y / A	Y / A	Y / A	Y / A
3.2 Administration	Y / A	Y / A	N / ?	N/ ?
3.4 Performance biases	N / ?	N / ?	N / ?	N / ?
4. Summarise external validity	Y / A	Y / A	Y / A	Y / A
5. Summarise the strengths of the basic science				
5.1 Directness	N / A	N / A	N / A	N / A
5.2 Empirical basis	Y / A	N / ?	N / ?	N/ ?
5.3 Methodological rigour	N / U	N / U	Y / A	Y / A
5.4 Validation	Y / A	Y / A	Y / A	N / A
6. Summarise uncertainty	N / U	N / U	N / U	N / U

Notation:

Y: the analysis required to communicate uncertainty was undertaken

N: the analysis required to communicate uncertainty was not undertaken

A: senior decision-makers were made aware of the implications of the results of the analysis

U: senior decision-makers were not made aware of the implications of the results of the analysis

?: assessment not possible

4. THE IMPACT OF DEBIASING ON UNCERTAINTY COMMUNICATION

Multi-criteria decision analysis relies on judgemental inputs from both decision makers and the stakeholders whom they consult. Eliciting these judgements is often subject to biases, which can undermine both the scientific standing, and the public interest objectives of the analysis (Morton and Fasolo 2009).

Montibeller and von Winterfeldt (2015) discuss debiasing techniques aimed to reduce and, if possible, eliminate biases in multi-criteria decision analysis. [12] They focus on four 'judgement tasks' that are central to most applications of multi-criteria decision analysis: generation of objectives and alternatives, development of criteria (directly related to the objectives), elicitation of utility or value functions over criteria levels, and elicitation of weights for criteria. [13], [14] For each of these 'tasks', Table 3 summarises the debiasing techniques proposed by Montibeller and von Winterfeldt.

Table 3: Summary of debiasing techniques, by 'judgement task'

'Judgement tasks'	Associated debiasing techniques
Generation of objectives and alternatives	Have a reasonably large set of objectives, and identify alternatives individually for each objective.
Development of criteria	Favour natural units for the criteria scales and, when these are not available, use unambiguous constructed criteria.
Elicitation of utility or value functions over criteria levels	Rely on value functions (as approximations of utility functions), and avoid overconfidence in the context of groups decisions.
Elicitation of weights for criteria	Devote the same level of detail to all objectives, and ensure that the upper and lower bounds for each criterion do not constrain any possible outcomes.

Source: adapted from Montibeller and von Winterfeldt (2015)

This section considers the impact that applying these techniques might have with regard to uncertainty communication. [15] It does so by mapping out, individually for each technique, the extent to which applying it might facilitate, or hinder, the analysis associated with each of the various steps in the protocol for uncertainty communication by Fischhoff and Davis (2014). [16]

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[12] *Specifically, Montibeller and von Winterfeldt (2015) focus on multi-criteria decision analysis approaches based on multi-attribute utility and value function, noting nonetheless that most of their findings "also apply for alternative methodologies".*

[13] *Montibeller and von Winterfeldt (2015) cite five 'judgement tasks', but leave one of them out (assessment of the performance of the alternatives on the criteria). They do so because "there is a vast literature on biases in this task". For the same reason, this working paper too leaves this task out.*

[14] *A thorough description of these 'judgement tasks' is beyond the scope of this article. An annex gives a basic introduction to multi-criteria decision analysis (Annex 1). Detailed descriptions can be found in Keeney (2009), and Belton and Stewart (2002).*

[15] *The authors were involved in the implementation of the applications discussed, which makes it possible to hypothesize about that impact that debiasing might have had, had it actually been conducted.*

[16] *The analysis considers four types of uncertainties: aleatory, epistemic, parametrical, and model-related (Bedford and Cooke 2001). Other types of uncertainties, notably volitional uncertainty, are not considered, because they cannot be captured by the two tools used (the uncertainty communication protocol by Fischhoff and Davis, and the debiasing techniques proposed by Montibeller and von Winterfeldt).*

This is done for each of the two programmes introduced in Section 2. For each programme, all four debiasing techniques are applied, across all aspects of the programme: in the case of the 'technology needs assessment' programme, they are applied to both its 'mitigation' and 'adaptation' components; in the case of the 'adaptation priorities in Mexico' programme, they are applied to both its 'policy' and 'fund' components.

The assessment relies on the rationale implicit in the uncertainty communication protocol by Fischhoff and Davis, and in the debiasing techniques by Montibeller and von Winterfeldt. The former requires that the analyst checks whether certain types of information, which are required to communicate uncertainty, have been obtained (for example, whether or not 'variability' has been thoroughly evaluated and summarised). The latter require that a number of analytical steps are performed (for example, ensuring that the set of objectives is reasonably large). The assessment presented in this paper considers how the latter (i.e. performing these analytical steps) may facilitate, or hinder, the former (i.e. the examination of those uncertainty-related aspects of the analysis).

Findings are summarised in the following four paragraphs (one for each of the four 'judgement tasks' listed in Table 3). Table 4 synthesises the findings.

Generation of objectives and alternatives. The debiasing technique associated with this 'judgement task' can be summarised as follows: have a reasonably large set of objectives, and identify alternatives individually for each objective.

Applying this technique may make it more difficult to conduct the analysis required to communicate uncertainty with regard to the following issues:

- 'identify key outcomes and how to measure them' (because the larger the number of objectives, the more likely it is that some of the outcomes cannot be defined unambiguously);
- 'summarise variability' (because the larger the number of objectives, the more challenging it is to assess the variability of each of them);
- reduce 'performance biases' (because the larger the number of objective, the more likely it is that biases in performance are introduced, or existing biases are aggravated);
- 'summarise uncertainty' (because the larger the number of objectives, the more challenging it is to assess and summarise the uncertainty associated with each of them).

Applying this technique may make it easier to conduct the analysis required to communicate uncertainty with regard to the examination of 'selection biases', because having a larger number of objectives and alternatives is one of the best ways of countering biases in the selection process.

Development of criteria. The debiasing technique associated with this 'judgement task' can be summarised as follows: favour natural units for the criteria scales and, when these are not available, use unambiguous constructed criteria.

Applying this technique may make it easier to conduct the analysis required to communicate uncertainty with regard to the following issues:

- ‘identify key outcomes and how to measure them’ (because a carefully selected set of criteria is a pre-condition for effective outcome measurement);
- assess ‘selection biases’ and ‘attrition biases (because a carefully selected set of criteria helps ensure that all relevant parameters are reflected in the analysis, thus contributing to prevent both selection and attrition biases);
- ensure ‘methodological rigour’ (because a carefully selected set of criteria helps ensure that all relevant parameters are reflected in the analysis, thus contributing to increase the rigour of the method).

Elicitation of utility or value functions over criteria levels. The debiasing technique associated with this ‘judgement task’ can be summarised as follows: rely on value functions (as approximations of utility functions), and avoid overconfidence in the context of groups decisions.

Applying this technique may make it easier to conduct the analysis required to communicate uncertainty with regard to the following issues:

- ‘identify key outcomes and how to measure them’ (because well-conducted group elicitations can help avoid overconfidence in group assessments, which is a pre-condition for identifying key outcomes);
- ‘summarise variability’ (because the more carefully value functions are elicited and group elicitations are conducted, the more likely it is that the indicators used in the analysis reflect a wider range of uncertainties, thus helping assess and summarise the variability inherent to the analysis);
- assess ‘performance biases’ (because carefully elicited value functions are likely to be successful at gauging the extent to which the criteria are met, which is a pre-condition for eliminating performance biases);
- ensure ‘methodological rigour’ (because carefully elicited value functions and well-conducted group elicitations are pre-conditions for a methodologically rigorous analysis).

Elicitation of weights for criteria. The debiasing technique associated with this ‘judgement task’ can be summarised as follows: devote the same level of detail to all objectives, and ensure that the upper and lower bounds for each criterion do not constrain any possible outcomes.

Applying this technique may make it easier to conduct the analysis required to communicate uncertainty with regard to the following issues:

- assess ‘attrition biases’ (because carefully elicited weights ensure that each option receives the emphasis that it deserves, thus preventing attrition biases);
- ensure ‘methodological rigour’ (because carefully elicited weights are a pre-condition for a methodologically rigorous analysis).

Table 4: Impact of debiasing on uncertainty communication, by debiasing technique

Steps in the Fischhoff and Davis protocol for uncertainty communication	Debiasing techniques discussed by Montibeller and von Winterfeldt			
	Have a reasonably large set of objectives, and identify alternatives individually for each objective	Favour natural units for the criteria scales and, when these are not available, use unambiguous constructed criteria	Rely on value functions (as approximations of utility functions), and avoid overconfidence in the context of groups decisions	Devote the same level of detail to all objectives, and ensure the upper and lower bounds for each criterion do not constrain any possible outcomes
1. Identify key outcomes and how to measure them	Negative	Positive	Positive	No impact
2. Summarise variability	Negative	No impact	Positive	No impact
3. Summarise internal validity				
3.1 Selection biases	Positive	Positive	No impact	No impact
3.2 Attrition biases	No impact	Positive	No impact	Positive
3.3 Administration	No impact	No impact	No impact	No impact
3.4 Performance biases	Negative	No impact	Positive	No impact
4. Summarise external validity	No impact	No impact	No impact	No impact
5. Summarise the strengths of the basic science				
5.1 Directness	No impact	No impact	No impact	No impact
5.2 Empirical basis	No impact	No impact	No impact	No impact
5.3 Methodological rigour	No impact	Positive	Positive	Positive
5.4 Validation	No impact	No impact	No impact	No impact
6. Summarise uncertainty	Negative	No impact	No impact	No impact

In sum, uncertainty communication may be hindered when applying the debiasing technique associated with one ‘judgement task’ only (‘generation of objectives and alternatives’). This happens in no less than four out of six (sets of) steps in the uncertainty communication protocol by Fischhoff and Davis. Conversely, in one instance, application of the same debiasing technique can facilitate uncertainty communication (with regard to other steps in the protocol).

To a greater or lesser extent, application of the debiasing techniques associated with the remaining three ‘judgement tasks’ only facilitates, never hinders, uncertainty communication. Notwithstanding, and irrespective of the ‘judgement task’ considered, in most cases applying the various debiasing techniques has no discernible impact on uncertainty communication.

In all instances in which debiasing hinders uncertainty communication, it does so because it increases the complexity of the analysis. Indeed, applying the debiasing technique concerned (i.e. the technique associated with the judgement task ‘generation of objectives and alternatives’) makes it more challenging to ‘identify key outcomes and how to measure them’ ‘summarise variability’, reduce ‘performance biases’, and ‘summarise uncertainty’. Conversely, complexity is not a fundamental problem with regard to ‘summarise external validity’ and ‘summarise the strengths of the basic science’, the two (sets of) steps in which applying the debiasing technique concerned has not impact on uncertainty communication. [17]

In about half of the instances in which debiasing facilitates uncertainty communication, it does so because the analytical procedures associated with debaising effectively represent pre-conditions for successfully conducting multi-criteria decision analysis. This is true in three cases under (ensure) ‘methodological rigour’, two cases under ‘identify key outcomes and how to measure them’, and one case under (reduce) ‘performance biases’. The remaining instances in which debiasing facilitates uncertainty communication refer mainly to reducing ‘selection’ and ‘attrition’ biases, and ‘summarising variability’.

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[17] *It is worth noting that, in epidemiological studies, for example, where the results obtained through the population under study have to be applied to the (usually much broader) population of interest, debiasing may increase complexity and, for that reason, it may hinder uncertainty communication. This is not the case in the area of national-level planning for climate change, where the population being analysed, and the population of interest are effectively the same: they are, in both cases, the options a government has to mitigate climate change, and to adapt to it.*

5. DISCUSSION AND CONCLUSIONS

This working paper has presented two applications of multi-criteria decision analysis in the area of climate change: a simple application (the ‘technology needs assessment’ programme) and a complex application (the ‘adaptation priorities in Mexico’ programme). With regard to these two applications, the notation ‘N’ in Table 2 shows the various steps in the uncertainty communication protocol by Fischhoff and Davis (2014) for which the analysis required to communicate uncertainty was not undertaken.

It is not possible to determine the extent to which these two applications are representative of the range of multi-criteria decision analyses undertaken in the area of climate change. Nonetheless, it can be expected that, in some instances, similar outcomes can be observed. That is, it can be expected that, in some applications of multi-criteria decision analysis, the steps characterised with an ‘N’ in Table 2 are those where uncertainty communication is less likely to occur, unless specific provision to do so are introduced.

For each of the steps in the uncertainty communication protocol by Fischhoff and Davis, Table 4 synthesises the impact (positive, negative, or neutral) that four types of debiasing techniques might have on the analysis required to communicate uncertainty. As above, it can be expected that, in some applications of multi-criteria decision analysis, the steps characterised with ‘Negative’ (or ‘Positive’) in Table 4 are likely to be impacted by debiasing.

For the case studies considered, a cross-comparison of these two sets of observations highlights that efforts to characterise and reduce uncertainty may hinder uncertainty communication especially with regard to the following steps in the uncertainty communication protocol by Fischhoff and Davis:

- ‘identify key outcomes and how to measure them’ (step 1 in the protocol),
- ‘summarise variability’ (step 2 in the protocol),
- reduce ‘performance biases’ (step 3.4 in the protocol), and
- ‘summarise uncertainty’ (step 6 in the protocol).

These are the steps in the uncertainty communication protocol for which (i) the analysis required to communicate uncertainty was not undertaken in the case studies, and (ii) debiasing would affect negatively that analysis. Further research may therefore be especially warranted with regard to the approaches that can be used to effectively communicate uncertainty around these issues.

In conclusion, although the application of debiasing techniques can only be encouraged, such application should be complemented with heightened efforts to communicate the uncertainty associated with the analysis. In an area like climate change, where uncertainties can be very large, debiasing and uncertainty communication can in effect be considered as pre-conditions to sound policy-making.

Finally, it is worth highlighting that multi-criteria decision analysis, the decision-support tool examined in this case study, is but one of several aids utilised by decision-makers. How uncertainty characterisation and reduction (debiasing) impacts uncertainty communication with regard to the application of other decision-support tools has not been studied. Additional research in this area may be especially warranted in the context of cost-benefit analysis, which remains the most widely used decision-support tool. An annex (Annex 4) puts forward a number of possible elements to the answer of this question.

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ANNEX 1

Background on multi-criteria decision analysis

Given the ubiquitous nature of climate change, efforts to mitigate it and to adapt to it affect most areas of public policy. Because of this, decision-making for climate change is particularly challenging, in that it has to balance multiple, often conflicting, agendas (Urpelainen and Hughes, 2013). This is the background against which climate-change policy-makers are showing a growing interest in decision-support tools (Puig and Aparcana, 2016). One tool in particular (multi-criteria decision analysis) has gained popularity in recent years (UNEP, 2011).

Multi-criteria decision analysis is a decision-support tool that enables evaluation of options on the basis of pre-established criteria (Belton and Stewart, 2002). Unlike cost-benefit analysis, multi-criteria decision analysis does not require that inputs to the analysis are systematically translated into monetary values (or even quantitative values). Whilst cost-benefit analysis remains the most popular decision-support tool, even its proponents acknowledge that multi-criteria decision analysis “may be more comprehensive [than cost-benefit analysis] once goals beyond efficiency and distributional incidence are considered” (OECD, 2006).

DECISION-SUPPORT TOOLS

To make their choices, decision-makers may elect to review and update scientific evidence, act on the basis of intuition, or rely on a combination of both. When the first approach is chosen as the driver of the decision process, a range of decision-support tools can be used to guide the analysis of scientific evidence. The usefulness of a particular decision-support tool will depend on the type of problem at hand, and the context of the decision process (Table A1-a).

Table A1-a: Key features of selected decision-support tools

Tool	Decision criterion	Advantages	Challenges	Application
Cost-benefit analysis	Maximise the monetary value of social welfare	Perceived credibility Understandable metric	Monetisation and aggregation Ignored uncertainty	Well-specified interventions with tangible price-centred benefits and costs
Cost-effectiveness analysis	Minimise costs	Fixed ambition level Avoidance of monetising intangible benefits	Agreement on ambition level Ignored uncertainty Single solution	Well-specified interventions with important non-monetary targets
Multi-criteria decision analysis	Balance multiple objectives	Stakeholder engagement Integration of different metrics	Eliciting subjective judgements Multiple solutions may hamper consensus	Multiple and systemic interventions reflecting plural values and relying on a participatory approach

Source: adapted from (Scrieciu et al. 2014)

Multi-criteria decision analysis has been suggested as being especially well-suited to planning for climate change (UNEP, 2011). Reasons cited include: (i) it allows for an integrated treatment of socio-economic, ecological, institutional, and ethical perspectives; (ii) it can take into account issues such as morbidity and mortality, equity, environmental damage, catastrophic risks, and uncertainty; and (iii) its application is not limited to areas that can be described fully through monetary values.

A typical government-led application of multi-criteria decision analysis will rely on a consultation with stakeholders (UK DCLG, 2009). Stakeholders consulted may include government agency staff only, or a broader set of interested parties. Consultations may relate to technical aspects only, or to strategic issues, such as the boundaries of the analysis. A transparent and inclusive process will lend its results more credibility and legitimacy than it would otherwise be the case. Arguably, that combination of credibility and legitimacy is at least as important as the outputs of the analysis themselves (Belton and Stewart, 2010).

In its simplest form, multi-criteria decision analysis scores a number of options (for managing the problem of interest) against a range of indicators. Each indicator reflects the extent to which a criterion considered of importance for the decision is met (Box A1-a).[1] The option whose aggregate score is highest will in principle be the most appropriate option for responding to the problem being analysed.

Box A1-a: Multi-criteria decision analysis terminology in a public policy context

- ‘Policy options’ refers to the public-policy measures being considered to achieve the primary objective that is the object of the analysis.
- ‘Criteria’ refers to attributes that the different policy options being analysed and compared are ideally expected to have, which should be consistent with related policy goals.
- ‘Indicators’ are verifiable measures that can be used to monitor changes over time concerning the extent to which criteria are met.
- ‘Assessment methods’ are detailed descriptions of the analytical steps required to determine the value of the indicators.

Source: Adapted from UNEP (2011)

Even the seemingly straightforward procedure briefly sketched above presents analytical difficulties and governance challenges. Five examples follow:

- Incompatibilities between climate change mitigation or adaptation goals, and sector-specific development goals are commonplace in many jurisdictions (Jordan and Lenschow, 2010). The process of agreeing on specific criteria for the multi-criteria decision analysis will inevitably highlight these incompatibilities. This is because criteria should be consistent with all relevant established policy goals, which include goals driven by efforts to respond to climate change, and goals driven by other public policy priorities: if these goals are incompatible with one another, it cannot be expected that a criterion will be consistent with all or even most of them, as it ideally should be. Notwithstanding, by highlighting the problem, the multi-criteria decision analysis process might prompt government agencies to work on reducing those incompatibilities, which would be a positive outcome in itself.
- Agreeing on the relative weights associated with each criterion is fundamentally a political process, in that weights are used to reflect relevant established priorities (Belton and Stewart, 2002).[2] For example, a high relative weight on a group of indicators related to the financial aspects of a given decision will result in the option that is financially most attractive scoring higher, in aggregate terms, than it would have otherwise been the case. Simply stated, weights can largely determine the outcome of the analysis. Because of this, transparency and inclusiveness in the process of defining relative weights is a central aspect of multi-criteria decision analysis. Lacking such transparency and inclusiveness, the outcomes of the overall analysis will most likely enjoy less support from stakeholders.
- Indicators have to fully reflect the values embodied in the criteria to which they are associated, while remaining simple enough, so that it is possible for analysts to calculate the indicators. Data shortcomings and resource constraints (typically, limited availability to conduct the work on the part of government agency staff) may make it difficult to strike that balance (UNFCCC, 2009).
- Stakeholder consultations (to define indicators, criteria or relative weights) are often carried out in groups, as opposed to consulting stakeholders individually. These consultations are subject to a range of well-studied cognitive heuristics (Tversky and Kahneman, 1974). Of particular importance in the context of multi-criteria decision analysis is the apparent convergence of opinion associated with so-called group thinking (McCauley, 1989). This is caused by a generalised tendency in group dynamics to avoid conflicts, as well as by the dominance of the most charismatic persons in the group (who may not necessarily have greater expertise than the rest). As a result of this phenomenon, a process that was meant to promote and reflect 'group thinking' may in fact end up defeating its own purpose.
- The option that scores highest in aggregated terms may score below a certain threshold on one or several indicators, which might make that option unfit for purpose (Belton and Stewart, 2002). Defining the individual thresholds and deciding whether or not all are equally important requires a dialogue between scientists and policy-makers, who may lack the time required for it. Not least, there may be few precedents for such dialogue, whereby advice from scientists directly informs decision-making. Reversing that trend, where applicable, represents and added challenge for the multi-criteria decision analysis process.

NOTES

1. Relative weights are attached to each criterion. Weights are used to increase the relative importance of one or more criteria vis-à-vis the rest, when such differentiation is desired.
2. Note that, when criteria are so numerous that it becomes useful to cluster them by themes, weights are also assigned to each group of criteria, not just to criteria individually. Group weights, too, can be used to reflect relevant established priorities.

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ANNEX 2

A simple application of multi-criteria decision analysis: the ‘technology needs assessment’ programme

Promoting so-called technology transfer is a key tenet of the 1992 United Nations Framework Convention on Climate Change (Metz and Turkson, 2000). In this context, in 2008, parties to the convention endorsed the Poznan Strategic Programme on Technology Transfer, a key provision of which was the identification of ‘technology needs’ (at national level) in low-income countries (UNFCCC, 2008).

In response to this requirement, and with financial support from the Global Environment Facility, two rounds of ‘technology needs assessments’ have been completed, and a third round was launched in early 2015. The first round operated between 2004 and 2008, thus the facto preceding the formal requirements set in the Poznan Strategic Programme on Technology Transfer. The second round operated between 2010 and 2013. They targeted 92 and 33 countries, respectively. The third round kicked-off in early 2015 and targets 27 countries. This annex refers to the second round only because, thanks to the experience gained during the first round, the multi-criteria decision analysis process encompassed more sectors and relied on a wider stakeholder consultation, compared to the first round.

The goal of the ‘technology needs assessment’ process is to arrive at an official, prioritised list of mitigation and adaptation ‘technology needs’ at the national level. The overall process, which relied on multi-criteria decision analysis, is based on four overarching principles:

- **A broad definition**. As per the definition by the Intergovernmental Panel on Climate Change, ‘technology transfer’ is understood as “the broad set of processes that cover the flows of knowledge, experience, and equipment for mitigating and adapting to climate change” (Metz and Turkson, 2000). Stated differently, in the context of the ‘technology needs assessment’ process ‘technology transfer’ is defined broadly to include both ‘hardware’, and the skills and institutional infrastructures needed to adopt, operate and eventually produce that ‘hardware’ (de Coninck and Puig, 2015).
- **An official statement**. Given that the results of the work constitute a country’s official submission to the United Nations Framework Convention on Climate Change, the process in general and the results in particular have to be endorsed by all relevant parties (notably government agencies other than those directly concerned with climate change). Because of this, care was taken to set up, in each country, an institutional structure bringing together all relevant stakeholders, and to delineate clear roles and responsibilities for each (URC, 2010).
- **One methodological requirement**. The technology prioritisation process is based on a simple application of multi-criteria decision analysis. A spreadsheet is used to screen technology options (for responding to climate change) against a range of criteria.[1] Options and criteria vary across countries. One or more indicators per criterion are identified, to score each option against each criterion. In practice, two separate prioritisation processes are completed: one for technologies focused on mitigating climate change, and one for technologies focused on adapting to climate change (URC, 2010).

- **A flexible approach**. Countries are offered a great deal of flexibility with regard to the way they conduct the multi-criteria decision analysis. For example, the number of technology options (for responding to climate change) considered, and the rationale for selecting them, the breadth and number of the criteria and indicators utilised, and the extent to which stakeholders are involved, all vary across countries, in some cases significantly (URC, 2010). This flexibility allows countries to adapt the process to their respective national circumstances. For specific national details, the reader is referred to the individual country reports (available online at http://tech-action.org/).

Regional workshops are conducted, involving government representatives from the participating countries and other stakeholders, to introduce them to the international context for the work, as well as to the four principles outlined above. Not least, the workshops are used to provide hands-on training on multi-criteria decision analysis. This effort benefits from the lessons learnt during the first round of 'technology needs assessments', which has been compiled in a handbook (UNDP, 2010).

To guide the initial steps in the prioritisation process, and at the same time narrow down the list of potential target sectors, national greenhouse gas emissions inventories (for mitigation) and so-called national communications to the United Nations Framework Convention on Climate Change (for adaptation) are used. Thus, target sectors for mitigation are typically chosen among the highest emitting sectors (as identified in national inventories), whereas target sectors for adaptation are chosen among the sectors deemed most vulnerable (as assessed in national communications).

In keeping up with the flexibility principle, no constraints are imposed on the choice of technology options: country teams are free to entertain any potentially relevant option. In general, the options considered reflect the level of development of the country. For example, Senegal, the Dominican Republic and Mauritius prioritise, respectively, solar lanterns, fuel switching for public transport buses, and wind power. Only in few instances do the options prioritised seem slightly inconsistent with development levels (for example, carbon capture-and-storage in Thailand, and hybrid vehicles in Moldova).

The number and complexity of the criteria used (and of the associated indicators) varies significantly across countries, as does the extent and nature of the stakeholder engagement. Without attempting to prove it here, we postulate that these variations respond to differences in technical capacities and governance models.

Some countries have access to very competent specialists. In a few instances they are government staff. More often, however, they are consultants hired to manage the analysis on behalf of the government agency concerned. Such highly qualified specialists make it possible to identify criteria and indicator sets that reflect national priorities well. This improves the quality of the associated multi-criteria decision analysis process (Painuly, 2011).

Qualified specialists are found mainly, although not exclusively, in countries with the highest per capita income levels. In addition to suitable experts being available, tradition of participatory decision-making also determines the extent to which a skilled specialist is likely to engage. In countries with strong consultation traditions, such skilled specialists are both invited and eager to take on the work; conversely, in countries lacking consultation tradition, multi-criteria decision analysis is considered a lesser undertaking, and thus skilled specialists seldom engaged (Painuly, 2011).[2]

The extent to which stakeholders are consulted varies widely from one country to another. Governance models (participatory decision-making tradition in particular) obviously play a determinant role. Nonetheless, even when non-industry interest groups are consulted in an inclusive manner, they can seldom engage on equal footing with government and, especially, private sector stakeholders (Painuly, 2011). This is because, compared to other stakeholder groups, they have limited technical expertise, availability, and experience with economy-wide planning efforts.

In each country the prioritisation process results in a list of four-to-eight technologies for climate change mitigation, and three-to-six for climate change adaptation. In addition, assessments are conducted of the potential barriers to the adoption of the prioritised technologies, as well as of the means for breaking down those barriers. Not least, each country identifies a reduced number of immediate opportunities for deploying a sub-set of the prioritised technologies. For specific national details, the reader is referred to the various country reports (available online at http://tech-action.org/).

NOTES

1. Stakeholders were consulted (to a greater or lesser extent, depending on the country), and their views were used to develop the final list of criteria.
2. For example, in one of the participating countries a senior government official openly stated that a consensus-based process to policy-making in general, and a consensus-based identification of policy-relevant criteria in particular, would “never work” in the country.

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ANNEX 3

An advanced application of multi-criteria decision analysis: adaptation to climate change in Mexico's irrigated agriculture sector

In 2012, the federal government of Mexico passed the country's 'general act on climate change' (DOF, 2012). The act sets broad policy directions which current and, for the first time in Mexico, future governments have to abide to. The adoption of the act has been hailed as "a major advance in Mexico's actions to tackle climate change" (Nachmany *et al*., 2015).

The 'general act on climate change' provided for the preparation of a national strategy on climate change, which was released in 2013 (ENCC, 2013). The strategy lays out a limited number of mid- and long-term priorities, drawn from two longer lists based on purpose-developed analyses, and published separately (CICC, 2012), (INECC, 2012). A 2014 'special programme on climate change' articulates specific actions to be undertaken in the period 2014-2018, to initiate the implementation of those mid- and long-term priorities (DOF, 2014).[1]

The 'general act on climate change' also provided for the creation of a fund, aimed at "attracting and channelling public, private, domestic and international funding" to finance the implementation of the 'special programme on climate change' (DOF, 2012). The fund is administered by the Ministry of Finance (through a small group of Mexican financial institutions) and managed by the Ministry of Environment and Natural Resources (from the point of view of determining the most appropriate actions for the fund to target).[2]

During 2012 and early 2013 the Mexican Ministry of Environment and Natural Resources sponsored a **prioritisation process based on multi-criteria decision analysis**. The goal of the process was twofold: contribute to the identification of priorities for inclusion in the above-mentioned climate change strategy, and provide a tool for prioritising applications submitted to the board of the above-mentioned climate change fund. Three sectors were targeted: forests and land use management, water management, and irrigated agriculture. Of these three sectors, the irrigated agriculture sector was subject to the most comprehensive prioritisation process. Only this process is described here.

The prioritisation process led by the Mexican government drew on the United Nations Environment Programme's *MCA4climate Initiative* (UNEP, 2011). This initiative provides, among other resources, a criteria tree specifically designed for applying multi-criteria decision analysis in a climate change context, as well as thematic sets of criteria (and the corresponding indicators) for a range of climate change 'themes'. The Mexican government-led process adapted the MCA4climate criteria tree and its relevant criteria set to the realities of Mexico's irrigated agriculture sector.[3]

Through a facilitated workshop, senior government officials from different ministries, researchers, and representatives from various interest groups modified the generic MCA4climate criteria tree (Figure A3-a). To this end workshop participants were grouped according to their respective interests. For example, participants from both public and private banks formed a 'finance' group, while participants from environmental government agencies and environmental interest groups formed an 'ecosystems' group. In total, five groups were formed: finance, ecosystems, labour, policy, and climate change. Each group was asked to (i) define its subject area and (ii) state the importance of it with regard to adaptation to climate change in Mexico's irrigated agriculture sector. Subsequently, each group was asked to repeat the process, except that, this time, each group was asked to change subject area (for example, the 'finance' group had to focus on 'ecosystems'). Once all groups had considered all areas, a common definition for each area was agreed, on the basis of the five sets that had been produced. The five sets of statements of the importance of each area were used to modify the generic MCA4climate criteria tree.[4] Through a similar role-play, iterative process, the so-called analytical hierarchy process method was used to determine the weights of each criterion and group of criteria.[5]

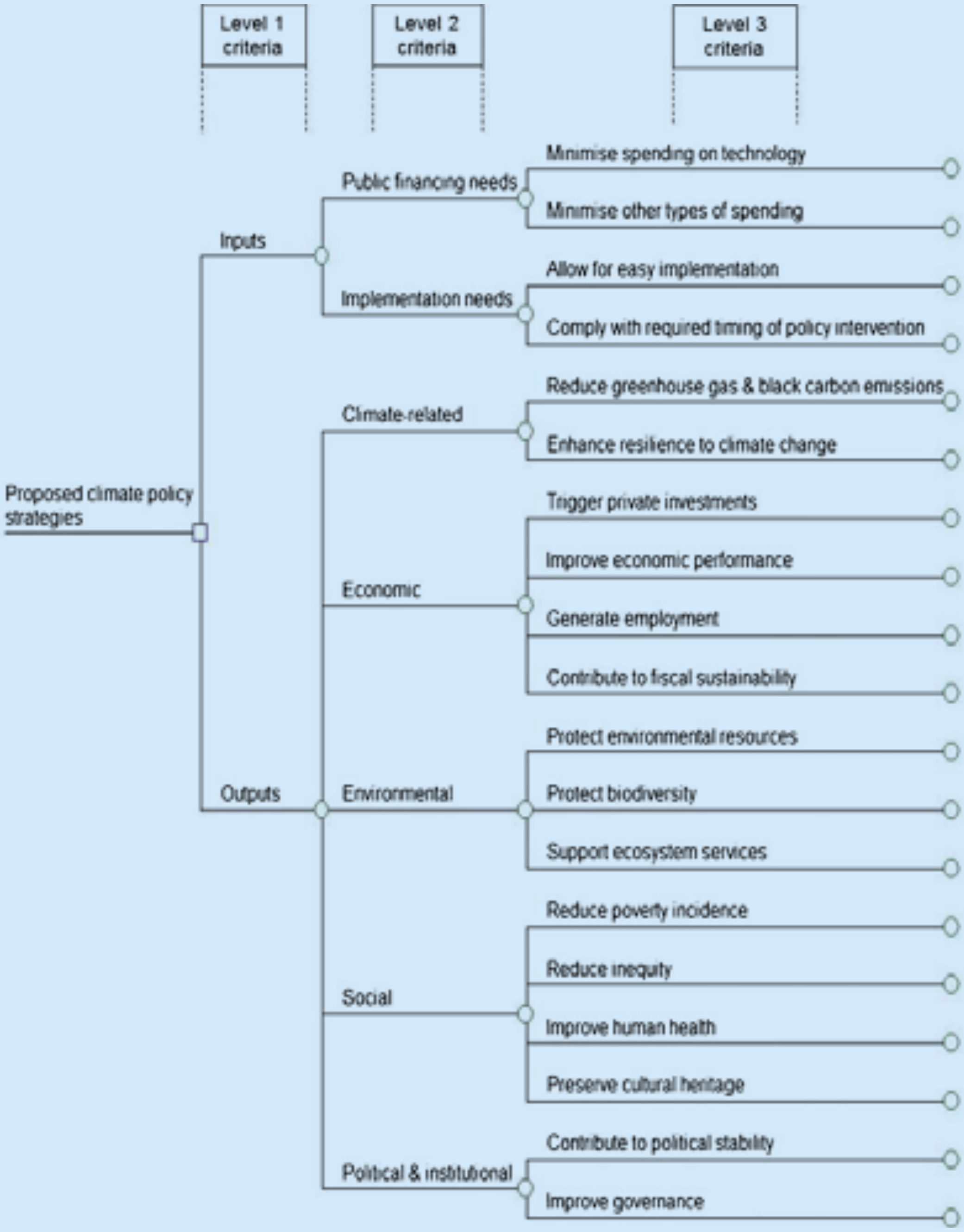
A different group of stakeholders was convened to define criteria and indicators. Like the first group, stakeholders in the second group came from different backgrounds, and had different interests. However, the second group was composed of individuals with an eminently technical profile (as opposed to the senior management profile of the individuals that made up the first group). The second group conducted its work under the assumption that the resulting indicators would be scored using multi-attribute utility theory, which had been described to them ahead of the workshop.[6]

The resulting model showed no sensitivity to small variations in the weights of the different criteria. Nonetheless, one criterion ('enhance resilience to climate change') dominated the scores even in implausible situations. For this reason, the indicator for that criterion was changed for a variation of it that showed a more realistic behaviour in the sensitivity analyses (SEMARNAT, 2014).

The resulting model was calibrated against a set of projects designed to promote adaptation to climate change in Mexico's irrigation agriculture sector. The projects had been subject to thorough ex-ante assessments, and were deemed to be effective and efficient in achieving their objectives. Minor changes in some indicators were required to obtain scores that showed no dependency to the geographic focus of the project or the type of measure introduced by it (SEMARNAT, 2014).[7]

The model has not been used for its intended purpose. Instead, senior policy makers in Mexico have chosen to replace the model with qualitative, case by case assessments. This is true for both the identification of policy priorities and the prioritisation of applications submitted to the board of the climate change fund. Reflecting this situation, the relevant paragraphs in the main text can only offer suggestions as to what might have happened, had the model been used.

Figure A3-a: MCA4climate generic criteria tree



Source: UNEP (2011)

NOTES

1. Specifically, the ‘special programme’ assigns responsibilities to stakeholders and sets time frames for the realisation of the various actions it identifies.
2. In 2013, senior environment ministry staff favoured a competitive application process for the selection of projects that would receive resources from the fund.
3. The MCA4climate initiative covers eight ‘themes’ in the area of adaptation to climate change and four ‘themes’ in the area of mitigation of climate change. ‘Reducing agricultural outputs losses’ is the MCA4climate ‘theme’ that comes closest to irrigated agriculture. The Mexican government-led prioritisation process used the criteria and indicators under this ‘theme’. Additional information on the MCA4climate initiative is available online at www.mca4climate.info
4. As a result, the ‘public financing needs’ cluster of criteria was combined with the ‘trigger private investments’ criterion (see Figure 1).
5. Analytical hierarchy process refers to a family of methods used to determine weights and scores in multi-criteria decision analysis (Saaty, 2000). These methods do so by establishing pairwise comparisons between weights and options. Several other methods are available, including so-called multi-attribute theory, linear additive models, or outranking methods.
6. Multi-attribute utility theory is one of several approaches for performance aggregation in multi-criteria decision analysis (Keeney and Raiffa, 1993). It relies on a pre-determined utility function that is used to aggregate the scores of each individual criterion (and, if relevant, group of criteria).
7. Type of measure refers to the dominant objective of a particular project, among those used to calibrate the model. These projects focused on one of the following objectives: improving infrastructures, providing technical assistance, strengthening coordination between related policy initiatives, and protecting natural resources.
8. For this reason, in the main paper the text that refers to this model is written in the ‘third conditional’ tense (for example, the papers states that “the Mexican programme would have been unlikely to suffer from selection bias”).

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ANNEX 4

Possible impacts of debiasing on uncertainty communication in cost-benefit analysis

Even though multi-criteria decision analysis can outperform cost-benefit analysis (Annex 1), the latter continues to enjoy comparatively wider acceptance by senior decision makers, partly because of its intuitive logic and universally understandable (monetary) metric. For this reason, it is useful to explore which aspects of uncertainty characterisation and reduction (the subset of these aspects that is relevant to cost-benefit analysis) might impact uncertainty communication.

The debiasing techniques that apply in the 'judgement tasks' 'elicitation of utility or value functions over criteria levels' and 'elicitation of weights for criteria' (Table 3 in the main text) are arguably similar to those that, in cost-benefit analysis, might apply to issues of valuation of non-market goods and services, and discounting for the future, respectively. In multi-criteria decision analysis, these techniques only facilitate the communication of uncertainty (Table 4 in the main text). Without attempting to demonstrate it, this working paper postulates that this would also be the case with regard to cost-benefit analysis.[1] Therefore, no further attention is paid to these two sets of techniques.

The debiasing techniques that apply to the remaining 'judgement tasks' in Table 3 ('generation of objectives and alternatives' and 'development of criteria') are arguably similar to those that, in cost-benefit analysis, might apply to the process of characterising the project of interest and its alternatives. Recall that, in multi-criteria decision analysis, the debiasing techniques associated with the first such 'judgement tasks' hinder uncertainty communication (Table 4 in the main text). It thus seems reasonable to expect that this might also be the case in cost-benefit analysis.[2]

Compared to multi-criteria decision analysis, in cost-benefit analysis the process of characterising the project of interest and its alternatives is often conducted with limited stakeholder involvement and, at times, using limited analytical evidence (Scrieciu *et al.*, 2014). As a result, uncertainties are more likely to remain unexplored and, for this reason, may be overlooked, if and when steps are taken to communicate uncertainty.

Against this background, this working paper argues that uncertainty communication is likely to be more challenging for cost-benefit analysis, compared to multi-criteria decision analysis. For this reason, and given the popularity of cost-benefit analysis, heightened emphasis on communicating uncertainties appears most warranted. This working paper further argues that debiasing techniques should be developed specifically for cost-benefit analysis, and indeed for all other major decision-support tools.[3]

NOTES

1. Section 4 in the main text outlines why the application of these two debaising techniques facilitates uncertainty communication. The same reasoning presented in section 4 with regard to ‘elicitation of utility or value functions over criteria levels’ is arguably valid in the context of valuation of non-market goods and services. This is because the more carefully value functions are constructed, and group elicitations are conducted, the more likely it is that a valuation of non-market goods and services considers all relevant aspects to it, which in turn makes it easier to determine (and communicate) the uncertainty associated with that valuation. Similarly, the reasoning presented in section 2 with regard to ‘elicitation of weights for criteria’ is arguably valid in the context of discounting for the future.
2. A parallelism similar to that outlined in the previous endnote could be made in this situation.
3. Ideally, and as per the main thrust of the working paper, the development of debiasing techniques should be complemented with guidance on uncertainty communication.

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