Combining quantitative techniques for selecting qualitative elements of socioeconomic scenarios adapted to a specific problem

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Socioeconomic scenarios are widely used in climate change research for modelling emissions of greenhouse gases, for assessing impacts and vulnerabilities, and for assessing mitigation and adaptation strategies. A new scenario framework aimed at facilitating the development of integrated scenarios where climate projections, assumptions about climate policy and socioeconomic scenarios (including qualitative storylines and quantitative elements) are integrated, is currently under development. A key feature of this new framework is that it will provide a flexible toolkit rather than a one-shot exercise. This toolkit is intended to meet a wide range of different needs in different research communities, and for this reason, the framework only provides limited information regarding regional and sector-specific specifications. This means that before the framework can be applied in concrete studies, further contextual details need to be developed by scenario analysts. This paper explores how three quantitative techniques – Cross Impact Balance, Scenario Diversity Analysis and Scenario Discovery – can be successfully combined in order to analyze and improve on the qualitative elements of socioeconomic scenarios.

Cross Impact Balance (CIB) is a method for constructing internally consistent qualitative scenarios. In a CIB analysis, relationships between states of scenario variables are systematically evaluated in order to find scenarios that are self-consistent. In the process of assessing all possible combination of states for consistency, expert judgement can be used. One of the aims of CIB is to identify 'stable scenarios', i.e. scenarios that describe long-term stable trends. *Scenario Diversity Analysis (SDA)* addresses another criterion for "good" scenario sets, namely diversity: how should scenarios be selected such that they span as wide a range of future developments as possible? A set that is too conservative may lead to underestimation of the need for action. In SDA a measure of distance between pairs of scenarios is defined based on the intuition that the distance is large when the distances between the states for each scenario variable are large, and the sum of all distances for each state is defined as the distance between two scenarios. This distance measure is used by the numerical algorithm of SDA to find a set of scenarios where the sum of all distances between the scenarios is maximal. *Scenario discovery* defines a scenario as a set of future states of the world that illuminate vulnerabilities of a proposed policy, that is, futures

where a policy fails to meet its goals. The approach begins with a computer simulation model that projects a policy's performance, using one or more outputs of interest, contingent on various uncertainties in those inputs. The model is run many times over an experimental design that samples different combinations of values for the uncertain model input parameters. Some criterion applied to the model outputs distinguishes those cases where the policy fails from those where does not fail. Statistical data-mining algorithms applied to the resulting multi-dimensional database then identify combinations of constraints on a small number of input parameters that best identify the cases in which a policy fails.

Differences and complementarities of the techniques

All three approaches utilize quantitative techniques for identifying a small number of scenarios out of the (often very large) set of possible ones. A main difference between CIB and SDA on the one hand and Scenario Discovery on the other hand is their relation to policy options. Policy options are typically seen as external to the scenarios that are analyzed using CIB or SDA, while policy options are integral to Scenario Discovery (in order to find the most relevant scenarios). Another way of expressing the difference is that CIB and SDA focus on structuring uncertainties, while Scenario Discovery focus on illuminating policies. Thus, Scenario Discovery is complementary to CIB or SDA. What is the relationship between CIB and SDA? CIB usually applies one set of rules to search for self-consistent scenarios. A naïve application of CIB therefore runs the risk of producing sets of scenarios that hew closely to one particular world view or of being too conservative, and this is exactly the property of a scenario set that DA aims to minimise. Thus, tradeoffs between the values of consistency and diversity can be explored by utilizing a combination of CIB and SDA.

Combining the three techniques

Combinations of the methods are analyzed and evaluated in terms of general usefulness, particular benefits and potential drawbacks. We start by analyzing two potentially useful types of combinations. 1) The first is to use CIB and SDA in connection. CIB is used to construct a set of scenarios that are free of internal inconsistency. SDA can be then applied on that set in order to construct a maximally spanning sub-set of scenarios. This combination can be used in order to explore tradeoffs between the values of consistency and diversity, either intuitively in an iterative fashion, or formally by defining a mathematical objective function that is optimized. 2) The second type of combination is to use CIB and SDA in order to refine or extend the results from Scenario Discovery. Remember that Scenario Discovery is typically used to generate clusters of scenarios that illuminate policy-relevant vulnerabilities. SDA can then be employed in order to select a small number of scenarios that efficiently represent these clusters. Also, scenarios generated by Scenario Discovery typically contain only on a few number of parameters. CIB can therefore be used to extend these scenarios to represent a broader context by considering factors not included in the Scenario Discovery simulations. Based on the results of this analysis we discuss other combinations and suggest potential case studies in the energy and climate domains.