Expert Workshop of the ADVANCE project

UNCERTAINTY IN CLIMATE CHANGE MODELING AND POLICY

Milan, May 13-14, 2014
Fondazione Eni Enrico Mattei
Corso Magenta 63

Minutes

Objectives

Uncertainty is a key component of climate change, characterizing both the science and the human response of a changing climate. Understanding the problem of climate change and formulating a set of policy responses will thus need to account for the key uncertainties at play, and to provide risk management strategies which are robust to such risks.

In the most recent years, new research has emerged with the potential to improve the way we model uncertainty in climate change policy. Advances in decision theory, dynamic and stochastic programming, and in data availability allows for a richer accounting of uncertainty than previously possible. Yet, important challenges remain in the applicability of these new methods to large scale integrated assessment models (IAMs) which are routinely used for assessing climate change policies.

The aim of this expert workshop is to provide an opportunity for reviewing the latest developments in uncertainty and risk analysis in climate change, and their potential applications to IAMs. The agenda is organized around three main sessions, covering the theoretical, numerical and applications aspects. The final part aims at compiling a set of insights and recommendations for modeling climate change policies under uncertainty.

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Tuesday, 13 May 2014

The workshop started at 11 with the opening remarks of Giuseppe **Sammarco**, FEEM Executive Director. He introduced the workshop welcoming the participants and presenting FEEM.

Objectives of the workshop and framing of climate change uncertainty in the ADVANCE project (Massimo Tavoni, FEEM)

Massimo Tavoni, FEEM, presented the objectives of the workshop and showed how climate change uncertainty is framed in the ADVANCE project.

Session I: Decision Making Under Uncertainty

Uncertainty and decision in climate change economics (Antony Millner, LSE)

Antony Millner**,** LSE, noted how models are needed to reduce the complexity of reality and make better decisions, even though in some cases big structural challenges arise. In particular, in climate change long time-scales and significant uncertainties induce different models to predict a wide range of results, especially in terms of impacts. The models also rely on economic structural assumptions not always thoroughly validated on the past, and not always accounting for unanticipated disruptive events (like the recent technological advance in the US). Millner then introduced the concept of decision making under deep uncertainty (or ambiguity), and mentioned the consequences of choosing alternative criteria to the most common expected utility framework. He also recalled the difference between ethical disagreement and empirical uncertainty, and how for the first one more effort could be spent for finding an aggregated consensus.

Abatement under ambiguity (Loic Berger, FEEM)

Loic **Berger**, FEEM, recalled how uncertainty is ubiquitous, with different sources and types. He introduced the concept of ambiguity, and the possibility of extending usual expected utility models of decision with explicit distinction between uncertainty and ambiguity aversion. This was then applied in a simple model of optimal abatement under the possibility of catastrophic event, first analytically and then numerically using real climate expert probability judgments. The extension to ambiguity aversion matters in the results: one should abate more today in order to decrease the ambiguous probability of suffering from a severe loss. These tools could help policy makers to aggregate and make more sense of the different results models provide.

Discussion

Roger Cooke questioned the need for ambiguity reasoning to support ambitious abatements. He also argued for greater clarity when using the concept of climate sensitivity. Erin Baker mentioned the possibility of learning in the uncertain decision process, even though modelling such a dynamics leads to computational difficulties. Elmar Kriegler emphasized the aspect of completeness of preferences.
A discussion was led about the normative appeal of ambiguity in climate change for modelling any policy recommendations. Millner and Berger argued that the behavioural foundations but also axiomatic foundations of non-expected utility theories are relevant and usable in this context. Cooke

and Kriegler among others expressed some concerns about the usability. There was however an agreement that this is an important and ongoing debate.

13.00 - 14.00 Lunch

Session II: Incorporating uncertainty in IAMs

Integrated Comparison of Uncertainties in Climate Change Mitigation (Haewon McJeon, PNNL)

Haewon McJeon, PNNL, described the GCAM Integrated Assessment Model framework, and how its components are subject to uncertainty. He reviewed some Monte Carlo studies performed in the past, emphasizing a recent work where 161 thousand combinations of technology assumptions were implemented and the corresponding results visualized in galaxy-like plot. An overview of his other most significant works dealing with uncertainty followed: exploring combinations of technologies that are most vulnerable to exceed threshold stabilization costs, assessing probabilities of technology success, calculating optimal act-then-learn strategies, trading off technological and climatic uncertainties via stabilization targets, and designing robust energy efficiency policies for buildings.

FEEM: Selection of robust climate policies under current knowledge of uncertainties (Laurent Drouet, FEEM)

Laurent Drouet, FEEM, reminded how uncertainty permeates climate change modelling, and how this can be taken into account in climate decision making. Using the model outcomes produced for the AR5, Drouet explored a large space of possible future emissions/mitigation cost scenarios. He also assessed a probabilistic relation between cumulative emissions and induced changes in temperature, and between temperature and economic impacts. He finally combined all this information with several decision criteria, showing how different choices lead to different optimal carbon budgets, testing also for the importance of time preference, risk aversion and ambiguity aversion. Surprisingly, only one type of decision criterion would lead to policies consistent with 2°C.

Discussion

A discussion followed. Elmar Kriegler (PIK) asked some insights about the expected utility function and the selected carbon budgets showed by Drouet. The importance of the type of sampling used in Monte Carlo exercises was also mentioned as a convenient way to cut the order of magnitude of runs required. The availability of comprehensive databases of scenario and model runs as from the recent IPCC AR5 report and others was seen as a great potential to derive robust decisions under uncertainty.

R&D Decision Making Frameworks (Erin Baker - U. Mass**)**

Erin Baker, U. Mass, posed the question of R&D funds allocation across competing clean energy technologies, given that the the outcome of R&D is uncertain. Her approach consisted in integrating expert judgments on future prospects for technology with economic models of interactions between technologies, climate, and economy. She presented probabilistic estimates of future costs and efficiencies for a set of technologies, as elicited from experts in the TEaM project. Using importance sampling to better capture the costs of interest, and adopting a two-stage decision framework, it was

possible to calculate optimal R&D portfolio investments for different stabilization targets and teams of experts. Results vary across both of these dimensions.

Global sensitivity analysis and climate change (Emanuele Borgonovo - Bocconi Univ.)

Emanuele Borgonovo, Bocconi Univ., emphasized the need to introduce robust sensitivity practices in Integrated Assessment Modelling. He overviewed several sensitivity methods, focusing on the probabilistic ones, and mentioning pros, cons, caveats and potential remedies. He then explained different settings of a sensitivity analysis, including prioritization of uncertainty drivers, understanding of model first order response to change in inputs, and monotonicity of that response. He eventually recalled the results of a factor analysis done for the DICE model, and mentioned other ongoing works.

Discussion

Several modelers expressed great interest in the methods outlined by Borgonovo to apply to model runs. A discussion about the feasibility of implement the substantial number of model runs to be performed in the context of climate-energy models followed. Regarding the expert elicitation study of Baker, the need of expert estimates in particular on yet to be implemented on a large scale technologies was reiterated. A concern was raised with regard to the elicitation so far only referring to two countries and the validity of the data for global applications. Cooke maintained that additional information such as subjective confidence given by experts could be used to improve the precision of the estimates.

Wednesday, 14 May 2014

Session III: Managing risks and vulnerabilities

Instrument effectiveness and uncertainty: a review of empirical and model findings (Antony Patt - ETH)

Antony Patt, ETH, first talked about various uncertainty sources and their type and extent, as they emerge along the dimensions of climate policy choices and scale of action. He then moved to consider how investments are sensitive to changes in the likelihood of profitability or loss, bringing evidence from the literature in the energy sector. In particular, he showed how investors in low carbon technologies could be influenced by the uncertain future market and regulatory conditions, and how different climate policy instruments may have a an effect on altering such uncertainties. He then challenged the idea that a carbon price is what is needed to stimulate low-carbon investments, or that it is the most efficient way of doing it, as a lot of imprecision and perceived risk affect the decision making of investors.

Messaging Uncertainty in Climate Change (Roger Cooke – RFF)

Roger Cooke, RFF, observed that despite the guidance notes for IPCC lead authors for treating numeric assessment of uncertainties consistent, climate change scientists still sometimes convey misleading messages when quantifying uncertainty. This may favour deniers and alarmists, to the detriment of science-based communication. Cooke then touched briefly on how people, and in particular experts, can violate basic rules of probability and logic. This is crucial, especially when considering estimates from expert judgments, where a good balance of information and statistical accuracy should be sought. He eventually mentioned the issue of aggregating expert elicitation responses with a proper weighting scheme. His suggestion is to assign weights that reflect the accuracy and variability of experts evaluated with a preliminary set of training questions.

Discussion

The role of regulatory uncertainty for investment and costs as outlined by Patt was discussed as an important potential barrier to the implementation of technology intensive low carbon transitions. The methods of measuring e.g., differences in capital costs across countries was discussed and referred to future work by Patt. Cooke's points were well taken in particular the need to elicit data and expert estimates for instance for renewable technologies. In particular, improvements in the design and interpretations of expert elicitations were discussed and agreed to be important for the numerical model implementations and the use of different decision criteria under uncertainty. Millner argued that including for considering ambiguity this improved elicitation data is very relevant. Cooke maintained his opinion on the expected value as the normative criterion that should be considered for policies.

Presentation from main modeling groups on their experience in incorporating uncertainty into IAMs (Celine Guivarch – CIRED, Volker Krey – IIASA, Elmar Kriegler – PIK, Gauthier De Maere – FEEM, Ilkka Keppo – UCL)

Celine Guivarch, CIRED, presented two approaches her team followed to include uncertainty in a IAM. First, they performed a sensitivity analysis with many runs of a deterministic model (ex ante uncertainty on model parameters) exploring a large space of socio-economic assumptions, according

to the SSP framework. Second, they considered a built-in uncertainty/stochasticity within a model run, in particular on damages and social preferences, experiencing potentially higher optimal abatement levels.

Volker Krey, IIASA, explained how with his colleagues he set up an optimization problem minimizing not only expected costs, but also a risk measure of those costs. Using a reduced-version of the MESSAGE model, and considering only economic uncertainties, the resulting hedging strategy visibly reduced the 99th percentile of costs. Then, Krey showed how they used Latin Hypercube Sampling to efficiently evaluate the implications of assuming particular investment cost distributions for a set of key energy technologies.

Elmar Kriegler, PIK, first focused on major conceptual problems of using cost-effectiveness analysis for climate targets framed as constraints on the probability of crossing a certain threshold. He then presented a cost-benefit approach where two different welfare and policy outcome evaluation methods are compared. Eventually, he presented a study on the joint effect of uncertainty and heterogeneity of climate damages on climate policies, considering how this could be compensated with a proper insurance for various society risk and inequality aversion assumptions.

Gauthier De Maere, FEEM, summarized the major topics related to uncertainty on which FEEM has been working on. He then mentioned stochastic programming and approximate dynamic programming as two of the main computational methods successfully applied to IAMs for exploring problems with uncertainty, like assessment of optimal R&D portfolios and option values of innovative mitigation technologies. He concluded encouraging the opportunity to spot and leverage on synergies across different methods.

Ilkka Keppo, UCL, explained some of the research activities related to uncertainty undertaken at UCL. He first spoke about the implementation of stochastic programming in TIMES models, with an application to multi-stage stochastic decision making on R&D investments. He then presented an energy system model designed to run in a Monte Carlo mode, used for recent assessments on the likelihoods of meeting targets with predetermined emission price trajectories. Eventually, a work on exploring the space of near optimal decarbonization pathways with different techniques was shown.

Discussion: how to integrate uncertainty in climate change modeling and policy (*Chair:* Valentina Bosetti – FEEM)

The main points emerged in the workshop were summarized and are reported bellowed.

- Quantifying uncertainty (e.g. assessment of subjective probabilities through expert elicitation, aggregation of multiple model results, estimation of confidence intervals) is crucial to address for climate decision making.
- New frontiers of research are underway, and include alternative decision criteria beyond the traditional expected utility framework, more comprehensive description of preferences (e.g. including ambiguity aversion or inequality aversion), combination of stochastic programming techniques with large IAMs, and global sensitivity analysis.
- Three crucial roles were identified for uncertainty: to increase credibility, reliability and transparency of integrated assessment models (e.g. global sensitivity), to better choose robust and flexible policies (e.g. criteria), to understand major socio-economic drivers and their relative roles in shaping future climate decision making.

List of Participants

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