The cautious modeller: craftsmanship without wizardry.

Preface to
Analyse de sensibilité et exploration de modèles
Applications aux modèles environnementaux

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According to Naomi Oreskes [2000] '*[…] models are complex amalgam of theoretical and phenomenological laws (and the governing equations and algorithms that represent them), empirical input parameters, and a model conceptualization. When a model generates a prediction, of what precisely is the prediction a test? The laws? The input data? The conceptualization? Any part (or several parts) of the model might be in error, and there is no simple way to determine which one it is*'.

Oreskes's point is linked to the parallel often made between a logical proposition – a theory-based statement - and a model prediction. Although models share the scientific flavour of postulated laws or theories they are not laws in that the making of a model is substantially more fraught with assumptions than crisp theories or agile laws ordinarily are.

She notes '*[…] to be of value in theory testing, the predictions involved must be capable of refuting the theory that generated them*.' What when the 'theory' is not a law but a mathematical model? '*This is where predictions […] become particularly sticky*.'

The crux of the matter is that model based inferences are very delicate artefacts. These artefacts can be immensely useful as well as dramatically deceiving. Foremost this is due to the fact that models lend themselves to a universe of possible uses. Philosopher Jean Baudrillard was among the many to note how different model use is between controlled laboratory conditions and – to make just an example – model use in mass communication [Baudrillard, 1999, p.92].

In his critique of man's addiction to a "simulated" version of reality he states:

One 'fabricates' a model by combining characteristics or elements of the real; and, by making them 'act out' a future event, structure or situation, tactical conclusions can be drawn and applied to reality. It can be used as an analytic tool under controlled scientific conditions. In *mass communication, this procedure assumes the force of reality, abolishing and volatilizing the latter in favour of that neo-reality of a model materialized by the medium itself.*

For Funtowicz and Ravetz different quality control standards apply to different contexts, depending mostly on the stakes associated to a model prediction (e.g. relevant to many versus relevant to a few), as well on the associated uncertainties [Funtowicz and Ravetz, 1990, 1993]. High stakes, high uncertainty settings call – also in the case of mathematical modelling – for forms of quality assurance beyond those in use within the discipline. In this respect the use of models' pedigree has been advocated by van der Sluijs (2002).

To complicate the matter further, prediction's stakes and prediction's uncertainties are not independent from one another, as – in a situation where stakes are high - competing parties may inflate or deflate the uncertainty associated to a model inference according to their convenience [Michaels, 2005;Oreskes and Conway, 2010].

A modeller quietly going about her business and toiling with algorithms to solve a technical tasks – be it a mechanism identification, an optimization, a *ceteris paribus* analysis, or an expert system may wonder in which way all this should be of concern. In a sense linked to Oreskes' initial remarks, the considerations above should be a concern to all modellers. How does the reader of the present manual <u>test</u> her model when it is built by combining a conceptualization, a set of laws and input data, with algorithms, boundary conditions and who knows how many other explicit or implicit assumptions? Depending on what kind of analysis the modeller is engaged she may be more concerned about the model's sensitivity to one or another of the features above. This implies that she must have a sure grasp, a firm understanding of what drives the inference of her model, foremost for herself, but also because she might be called to defend her analysis.

One way to invalidate a model is to bring out in the open the many assumptions possibly hidden in its construction (Laes et al., 2011; Kloprogge et al., 2011).

Recommendations along these lines can be found in several disciplines. A need for a global sensitivity analysis has been advocated by econometricians [Leamer 1990, 2010; Kennedy 2007], as well and by international agencies [EPA, 2009; OMB 2002, 2006] and practitioners [Saltelli, 2010]. The team running the Écoles Chercheurs MEXICO has made a fortunate choice in naming the present Handbook "Analyse de sensibilité et exploration de modèles", in that sensitivity analysis is foremost about exploring the space of the input assumptions is such a way as to be able to map the inference to the assumptions in a transparent fashion. Such a mapping is precious in several respects:

- Having done such a mapping the modeler will naturally tend to present her inference in the form of a distribution, or at least to give confidence bounds, avoiding the ludicrous spurious accuracy often accompanied to model inferences (e.g. giving an economic prediction with four significant digits when two would already be difficult to defend).

- Knowing what factors drive the variation in model prediction allows one to simplify models. When models are to be audited by an external entity a simplified model representation can be extremely useful, especially if guidelines applicable to the subject domain prescribe transparency, i.e. in the form of reproducibility by independent actors [OMB 2007].
- At the most basic level of the analysis, the mapping will most likely help identify inconsistencies or 'surprises' in the way the model reacts.

Still, sensitivity analysis (or sensitivity auditing, which is sensitivity analysis deployed in a context of scientific support to policy [Saltelli et al., 2012]) is no panacea. A few caveats are *de rigueur*:

- "*It is important […] to recognize that the sensitivity of the parameter in the equation is what is being determined, not the sensitivity of the parameter in nature. […] If the model is wrong or if it is a poor representation of reality, determining the sensitivity of an individual parameter in the model is a meaningless pursuit.*" [Pilkey and Pilkey-Jarvis, 2007].
- Some sensitivity analyses can be poor or perfunctory, either because of lack of ingenuity in their construction or because of a cavalier attitude with regard to uncertainties. To make just an example, a sensitivity analysis performed by changing one factor at a time is definitely a poor practice [Saltelli and Annoni, 2010].
- Simply because we do not know what we do not know, all sensitivity analysis will remain subject to an incompleteness principle. In controversial cases, the quality of a SA will be judged by its fitness for purpose, e.g. by its acceptance and defensibility.

We would like to conclude this short preface to the excellent work of our MEXICO team with a spoon of irony, borrowed from Douglas Adams, the popular author of the BBC's Hitchhiker Guide to the Galaxy. In one of his novels a character states (Adams, 1987, p. 69):

'*Well, […] [the] great insight was to design a program which allowed you to specify in advance what decision you wished it to reach, and only then to give it all the facts. The program's task, […], was to construct a plausible series of logical-sounding steps to connect the premises with the conclusion.*'

Modelling has been defined as an art, or better a craftsmanship (Rosen, 1991). Like all creative activities, modelling gives joy to its maker. Might the users of this manual enjoy their craft with a vigilant eye against malpractice!

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