What is wrong with evidence based policy?

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Abstract

The present crisis of science's governance, affecting science's reproducibility, scientific peer review and science's integrity, it is perhaps time to reconsider evidence based policy as it is being practiced at present.

Current evidence based policy exercises entail forms of quantification – often in the form of risk analysis or cost benefit analyses - which aim to optimize one among a set of policy options corresponding to a generally single framing of the issue under consideration. More cogently the deepening of the analysis corresponding to a single view of what the problem is has the effect of distracting from what could be alternative readings. When using evidence based policy those alternative frames become some kind of 'uncomfortable knowledge' which is de facto removed from the policy discourse. All the more so the more massive is the use of supporting mathematical modelling.

Thus evidence based policy may result is a dramatic simplifications of the available perceptions, in flawed policy prescriptions and in the neglect of the world view of legitimate stakeholders. This use of scientific method ultimately generates – rather than resolve – controversies and erodes the institutional trust of the involved actors.

We suggest an alternative approach – which we term quantitative story-telling – which encourages a major effort in the pre-analytic, pre-quantitative phase of the analysis as to map a socially robust universe of possible frames, a rich set of different lenses through which to perceive what the problem is. This is followed by an analysis where the emphasis in not on confirmatory checks or system optimization but – the opposite – on an attempt to refute the frames if these violate constraints of feasibility (compatibility with processes outside human control); viability (compatibility with processes under human control), and desirability (compatibility with a plurality of normative considerations relevant to the system's actors).

Key words: Evidence based policy, science for governance, STS, Post-Normal Science

1. Science advice at times of crises

The European Commission is often praised or blamed on reason of being a technocratic organization, where the use of science as input to policy is kept is high consideration. Hence it is not surprising that the symptom of a surging malaise are felt acutely in this institution. According to a former EC Chief Science Advisor (Anne Glover, cited in Wildson, 2014):

> *The incoming commission must find better ways of separating evidence-gathering processes from the 'political imperative'.*

There seems to be a mounting awareness that too often evidence based policy turns into its opposite, policy based evidence. The recipe to overcome these flaws appears - for those observers - a more strict separation of science and policy.

We intend to argue against this view, and to show that however desirable a pure model of separation between science and policy would appear to be prima facie, it is in practice not viable. The concomitant crises of science, trust and of sustainability call for different medicines that just separating facts from policy.

One should note that today in several cases where science is called to adjudicate a policy the level of conflict tend to be high. The provision of scientific input does not seem to quell controversies. For Dan Sarewitz (2000) science seems at time to be the problem rather than the solution: *"Rather than resolving political debate, science often becomes ammunition in partisan squabbling, mobilized selectively by contending sides to bolster their positions."*

Indeed science has not helped to defuse controversy on issues such as:

- the impact of pesticides on bees,
- the culling of badgers,
- greenhouse potential of the refrigerant liquid used by Mercedes Benz,
- impact of endocrine disruptors,
- benefits of shale gas fracking,
- fate of children raised by gay parents,
- true long term cost of citizenship for illegal migrants,
- desirability of international testing and comparison of the educational attainment of children,

… and the list, based on issues that have received mediatic attention in Europe and in the US, could go on.

The point could be made that the term 'wicked issues' (Rittel & Webber 1973), once reserved to intractable cases such as genetically modified organisms or climate, now applies to most issues where science is called to adjudicate.

Dan Kahan (2014) has observed that climate change affects us so intimately that it can define who we are culturally and normatively. If this is the case then we must draw the conclusion that our culture presently shape our attitude about a much larger class of problems, and that – as noted by Kahan – the more literate the observer is on a given issue, the higher his polarization is likely to be. It is as if facts – rather than settle the issue – were metabolized instead as ammunition to feed one's vision of the world.

Though apparently unrelated, the climate of controversy is not helped by science own crisis of integrity and legitimacy. Even mainstream non-academic publications have now registered the phenomenon. For The Economist – a periodical:

> *Science still commands enormous—if sometimes bemused—respect. But its privileged status is founded on the capacity to be right most of the time and to correct its mistakes when it gets things wrong.* […] *The false trails laid down by shoddy research are an unforgivable barrier to understanding.*

(The Economist 2013). Not content with devoting to the issue its cover, The Economist goes on to blame lack of statistical skills among scientists, e.g. in balancing false positives and false negatives, and poor refereeing practices.

Fraud and misconduct are only part of the story. Yet the retraction from the journal Science of findings according to which political activists could convince conservative voters to change mind on same-sex marriage in brief face-to-face conversations prompts the New York Times to title 'Scientists who cheat' (2015) and Nature (2015) to talk of 'Misplaced faith'. All news story that concerns science and science's integrity seem to jump very quickly from academic realm to the mediatic one. In the academic press proper the drop in reproducibility and the corresponding increase in retraction of scientific work are registered with increasing alarm, with scientific journal editors finding themselves in the first line of fire. Four international conferences have already been held on science integrity between 2007 and 2015 (Lancet, 2015), the issue is debated in think tanks (Horton 2015).

'Unreliability in scientific literature' and 'systematic bias in research' says Boyd (2013, Nature). "Laboratory experiments cannot be trusted without verification", argues Sanderson for organic chemistry research (2013, *Nature*). 'Suspected work […in] the majority of preclinical cancer papers in top tier journals' is denounced by Begley (2013,

Nature). In a landmark study of results in cancer science Begley and Ellis were able to reproduce only 11 per cent of the original findings (2012).

The situation is not different in the social sciences. Nobel laureate Daniel Kahneman – shocked by the lack of reproducibility of behavioral studies – prophesizes: "I see a train wreck looming" warns (Yong, 2012).

John Ioannides (2005) titles an influential paper: '*Why Most Published Research Findings Are False*'. The same author spearheaded the creation of a Meta-Research Innovation Centre (METRICS) in Stanford, to combat 'bad science', an initiative duly registered by The Economist, (2014), and in a subsequent paper claimed that as a result of shoddy science as much as 85% of research funding is wasted.

For the Lancet (2015) – which ran in 2014 a 'Series on Research: increasing value, reducing waste' - an estimated US$200 billion was wasted in the US in 2010.

There is also a proliferation of initiatives taken to tackle retractions; see, for example http://retractionwatch.wordpress.com), and http://www.reproducibilityinitiative.org, (Nature Biotechnology, 2012). Fixing things is nevertheless not straightforward as '*Sluggish data sharing hampers reproducibility effort*', (Van Noorden, 2015).

The journal Nature notes that in the UK the public trusts scientists much more than scientists think, according to an Ipsos MORI poll, 'But should it?', it asks.

The peer review system at the hearth of science's quality control mechanism is at the hearth of the crisis. "*Springer and Université Joseph Fourier release SciDetect to discover fake scientific papers*" announce the editor Springer (2015), meaning by this that as spoof papers are now routinely produced by malicious software, the editors need to fight on the same ground with a counter software. The situation of authorship is also critical. The journal Science titles "*China's Publication Bazaar - A Science investigation has uncovered a smorgasbord of questionable practices including paying for author's slots on papers written by other scientists and buying papers from online brokers*".
There are lines of tension between science and its editors. Timothy Gowers campaign against Elsevier with the slogan 'Academic Spring' (Whitfield, 2012), to fight what he considers an outrageous pricing policy. Brave librarians such as Jeffrey Beall at the University of Colorado, Denver, fight against 'predatory publishers', who charge authors for publishing but do not provide any control or peer review (http://scholarlyoa.com/2015/01/02/bealls-list-of-predatory-publishers-2015/). A recent discussion of the present convulsions in peer review and quality control is in Funtowicz, and Ravetz, (2015).

The present crisis of science did not manifest overnight. At root one of science's crisis could indeed be science's own success. In his 1963 work 'Little Science, Big Science' Derek J. de Solla Price prophesized that Science would reach saturation (and in the worst case senility) under its own weight, victim of its own exponential growth (pp 1-32). de Solla Price is considered today the father of scientometrics. Yet his forewarnings on the impossibility for science to grow for ever, the implicit dangers in the shift from little to big science received relatively less attention.

Jerome R. Ravetz offered an additional warning. In his 1971 book 'Scientific Knowledge and its Social Problems' he notes (p.22):

> *[…] with the industrialization of science, certain changes have occurred which weaken the operation of the traditional mechanism of quality control and direction at the highest level. […]The problem of quality control in science is thus at the centre of the social problems of the industrialized science of the present period. If it fails to resolve this problem […] then the immediate consequences for morale and recruitment will be serious; and those for the survival of science itself, grave.*

Ravetz identified in the system of quality control the fault line which would run the greatest risk when science – which is after all a social activity – dramatically changed its ethos, and when its actors would be the subject of a deep changes in the system of reward and incentives. The centrality of ethics for the quality and the self-governance of science so clearly illustrated by Ravetz is also central to the work of Jean-François Lyotard. In his 1979 work 'La Condition postmoderne. Rapport sur le savoir' he tackles the de-legitimization of knowledge (identified with science) when this becomes an industrialized commodity – as opposed to the instrument of emancipation and betterment of human beings (*bildung*).

Coming to more recent works, Philip Mirowski describes the degeneration of industrialized science in the US with painstaking detail in his work (2011) 'Science-Mart: Privatizing American Science'. According to Mirowski after the eighties neoliberal ideologies succeeded in decreasing state intervention in the funding of science, which became increasingly privatized and sub contracted, generating the perverse system of incentive already mentioned by Ioannides.

In conclusion of this discussion of science's own crisis we note that the use of science for policy is based on trust, and cannot be independent from what is happening in the science's own house. More specifically the same Lyotard (work cited) notes that since the age of Plato the legitimacy of science is linked to the legitimacy of the legislator:

> '*Who decides what counts as knowledge and who knows about what one must decide?* […] *The question of knowledge in the information society is more than ever the question of government*'.

'*Solutions to the problem of knowledge are solutions to the problem of social order*' is a conclusion of Steven Shapin & Simon Schaffer 1985 book 'Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life'. Thus our chosen epistemologies are not just issues for debate in philosophical circles, but have a direct bearing on the polity. This brings us back to Anne Glover's diagnosis and therapy of what needs to be done to fight the sins of 'policy based evidence'. She advocates strengthening the separation between science and policy. This epistemology, known as 'demarcation model' (Funtowicz, 2006), is at present the most widespread, and aims at protecting science from the political interference, preventing possible abuse of science and scientific information driven by agendas. It prescribes a clear demarcation between the institutions (and individuals) who provide the science and those where it is used. Why should we abandon this model? Just for its lack of realism?

The prevailing scientist-policy maker dichotomy, whereby scientists claim to (or are expected to) produce and certify the facts and policy makers claim to guarantee the legitimacy of the values neglects the fact that in present arrangements science's input to policy take place in hybrid settings – with a rich spectrum of actors and competences, from the practicing scientists to the entrepreneur researcher, from the technology regulator to the staff on the policy file, often active in boundary organizations operating at the science, law and policy interfaces, under close and eager mediatic scrutiny and interest groups pressure. In these settings, facts and values are intermingled. Instead of purified facts we mostly deals with hybrid arrangements (Latour, 1991), and one of the features of the present epistemic governance crisis is that "*the more knowledge is produced in hybrid arrangements, the more the protagonists will insist on the integrity, even veracity of their findings*" (Grundmann, 2009).

Our discussion of science advice at times of crises concludes with an analysis of statistical or mathematical modelling, a fundamental ingredient of science's input to policy, and of the related issue of quantification. We shall argue that in this field the present arrangements are particularly problematic.

We start with a well-known example where science was recruited to advocate austerity in public budgets. A 90% ratio of public debt to gross domestic product was stipulated by Harvard professors Kenneth Rogoff and Carmen Reinhart as an absolute ceiling above which growth would be hampered. Thus debt ratios above this limit were defined as unsafe for a country. A later reanalysis by researchers from the University of Massachusetts at Amherst disproved this finding by tracing it to a coding error in the authors' original work. Clearly once this particular result was repudiated the policies had already be put in place and "*In Britain and Europe, great damage has been done as a result*." (Cassidy, 2013).

This is but one of the many instances where improper use of mathematical modelling has been instrumental of supporting flawed policies. Modelling hubris and its

consequences are discussed in (Saltelli et al., 2013, Saltelli & Funtowicz, 2014). In his 2013 work 'Never Let a Serious Crisis Go to Waste: How Neoliberalism Survived the Financial Meltdown' Philip Mirowski devotes a long section (pp 275-286) to the story of how dynamic stochastic general models (DSGE) were the subject of a hearing in the US senate – '*an event in 2010 that was literally unprecedented in the history of economic thought in America*', p. 275, with sworn testimony of economists such as Sidney Winter, Scott Page, Robert Solow, David Colander and V.V. Chari, to understand how 'theorists tools' had come to be used as policy instruments and why these instruments were all but useless in anticipating the economic crisis. Queen Elisabeth had a similar moment with British economists at the London School of Economics (Pierce, 2008).

Saltelli and Funtowicz (2014) list several problems in the way mathematical modelling is used to tame uncertainty in relation to the production of evidence for policy. These include the rhetorical or ritual use of possibly disproportionate mathematical models to impress or obfuscate, the reliance on tacit possibly unverified assumptions, the instrumental inflation or deflation of uncertainties according to expedience, the instrumental compression and linearization of the analysis as to tame complexity and to convey an impression of prediction and control, and finally an absent or perfunctory sensitivity analysis.

2. Lessons to be unlearned: the Cartesian dream

Before we move to suggest how the present predicaments of science advice should be tackled we would like to ascertain what needs to be unlearned of our present wisdom in order to achieve progress. We call this the Cartesian dream, and try to identify elements of the dream from which modernity should perhaps awaken from. The antecedent of the dream is due to Francis Bacon (1561-1626), with subsequent formulations by René Descartes (1596-1650), a century later by Nicolas de Caritat, marquis de Condorcet (1743-1794), and in modern times by Vannevar Bush (1890-1974).

Bacon's utopia, as described in the Magnalia Naturae, an appendix to the New Atlantis (Bacon, 1627), includes "*wonders of nature, in particular with respect to human use*", which starts with "*The prolongation of life; The restitution of youth in some degree; The retardation of age; The curing of diseases counted incurable; The mitigation of pain;"* and continues with a long list of items, to conclude with "*Artificial minerals and cements"* – a list largely realized by modern technoscience

For Francis Bacon "Knowledge and power meet in one". For Descartes (1638, part 1) the learning of the humanistic tradition does not constitute clear knowledge but just a source of 'doubts and errors' and must abandoned in favour of the universality and mathematics and geometry.

One century later Condorcet was so convinced of physics' ability to solve human predicaments that in the Ninth Epoch of his 'Sketch for a Historical Picture of the Progress of the Human Spirit' he states: "*All the errors in politics and in morals are founded upon philosophical mistakes, which, themselves, are connected with physical errors*" (Condorcet, 1785).

Closer to our times Vannevar Bush's dream was couched in the Endless Frontier metaphor (1945): "*One of our hopes is that after the war there will be full employment. […]To create more jobs we must make new and better and cheaper products […] new products and processes are not born full-grown. They are founded on new principles and new conceptions which in turn result from basic scientific research."*

The limits of the Cartesian Dream have been exposed by a copious literature, from Stephen Toulmin's 'Return to Reason' and 'Cosmopolis' to Paul Feyerabend's 'Against Method', from Lyotard's 'The Post-Modern Condition' to Bruno Latour's 'We have never been modern'. The cost of this social critique was that a major science war was fought between natural and human sciences in between the eighties and the nineties[i].

Still today the Cartesian dream, which has in mathematics and physics the ideal model of how to tackle society and its problems, is prevailing.

As discussed by Stephen Toulmin in 'Cosmopolis, The Hidden Agenda of Modernity' the XVII century vision of Cosmopolis, a society as rationally ordered as the Newtonian physics, perpetrated - thanks to its extraordinary success in many fields of endeavour - an agenda of prediction and control; an agenda whereby ecosystems and social systems could be fitted into precise and manageable rational categories. The agenda now struggles against the complexities of the present crisis, endangering the legitimacy of the existing social contracts. The fact that the present 'evidence based policy' model clearly subscribes to the Cartesian dream has worrying consequences. The most serious is perhaps in that it induces dramatic simplification. Other terms we could use to describe these simplifications are 'Hypocognition' (Lakoff, 2010), or 'Socially constructed ignorance' (Ravetz, 1986; Rayner, 2012).

How does the simplification of evidence based policy manifest itself? This occurs through the mechanism of quantification, which is predicated on a selection of a problem structuring (the adoption of a frame). The selection determines a compression of the aspects that can be considered relevant when observing the external world, and when selecting a limited subset represented in a finite information space. This compression then determines the fragility of the inference based on the chosen simplified representation. The consequence of this process is explained by Rayner (2012) in terms of socially constructed ignorance, which is not the result of a conspiracy but of the sense-making process of individuals and institutions:

> *To make sense of the complexity of the world so that they can act, individuals and institutions need to develop simplified, self-consistent versions of that world. The process of doing so means that much of what is known about the world needs to be excluded from those versions, and in particular that knowledge which is in tension or outright contradiction with those versions must be expunged. […] But how do we deal with […] dysfunctional cases of uncomfortable knowledge […]?*

The unavoidable compression associated with the forced choice of a finite representation of a state of affairs comes to a cost and can lead to the degeneration of a given arrangement, when generalized and institutionalized, eventually producing a situation of Ancien Régime. Then the inability of the system to cope with stressors - e.g. the acknowledgment of the relevance of alternative representations - leads to a strategy of denial, and to the refusal to process either internal or external signals, including those of danger (Funtowicz and Ravetz, 1994).

The compression of the choice of a given perception/representation of a state of affairs results into ignoring knowledge which is available in established scientific disciplines which is not considered in the given problem structuring. Rayner call these the "unknown knowns", e.g. that knowledge which exists out there in academia and society but is actively removed by the compression. For Rayner "*unknown knowns* [are] *those which societies or institutions actively exclude because they threaten to undermine key organizational arrangements or the ability of institutions to pursue their goals.*"

Also ignored after the compression are the "known unknowns" – knowledge of gaps and areas of ignorance which is available but is not considered as relevant in the chosen issue definition. The result of this compression is to focus the attention of the analysts on a finite set of attributes and goals. This fatally calls for process of optimization, e.g. the analyst ends up investing time and energies to find the best solution in the wrong problem space.

Needless to say the hubris generated in this way increases fragility, foremost in relation to "unknown unknowns", as the optimization implies a reduction of the diversity of behaviours (because of the elimination of the less performing alternatives within the chosen problem structuring) and therefore a reduction of adaptability (because of the neglect of attributes and goals not considered in the optimization). The issue is discussed at length in Nassim N. Taleb work 'Antifragile' (2012).

A lesson from bioeconomics (Giampietro et al., 2013) is that sound science calls for addressing and integrating relevant events and processes that can only be observed and described by adopting simultaneously non-equivalent narratives (dimensions of analysis) and different scales (descriptive domains). In this case the virtue of reductionism (making possible rational choices based on a clear identification of relevant attributes, causes and goals) becomes a vice. A rationality based on a simple

problem structuring that is applied to solve a complex issue becomes a "mad rationality" – a concept attributed to social philosopher Lewis Mumford. The example of bioethanol from corn, where hundreds of billions of tax payer money have been invested in developing an alternative energy source that consumes more or less the same amount of energy carriers that it produces can be a good example of this effect (Giampietro and Mayumi, 2009). The story could continue to discuss how the same biofuels are considered in the public discourse as a strategy to mitigate emissions, when this appear to be the case only because of cuts in food production (Searchinger et al., 2015).

Socially constructed ignorance can also be defined as the institutional hegemonization of a given story-telling - i.e. the pre-analytical choice of a given set of relevant narratives, plausible explanations and pertinent perceptions and representations - which is assumed, by default, to be valid in normative, descriptive and ethical domains. This may lead to ignoring the elephant in the room, especially when the chosen hegemonic story-telling has been dressed by a convenient suite of indicators and mathematical modelling.

Famous instances of missed elephants are the presidential address to the American Economic Association of the Nobel laureate in Economics Robert Lucas in 2003 announcing that the "*central problem of depression-prevention has been solved*" once and for all; and the 2004 the 'great moderation' speech of Barnenke, Chair of the US Federal Reserve, about the successful taming of volatility of business cycle fluctuations. In both cases top ranking exponents of the ruling paradigm were unaware of the possibility of the financial collapse that would lead to the world economic crisis in the next years.

These blunders have fed into present urgent calls for a reconsideration of the prevailing paradigm in Economics (Reinert, 2008, Mirowki, 2013, INET, 2013). More radically some voices have called for a reconsideration of Economics as the authoritative discipline to adjudicate social and environmental issues (Ravetz, 1994, Giampietro, 2012, p. 104, Fourcade et al., 2014). Noting the state of the economic discipline as used to solve socioeconomic problems one cannot help considering the possibility that the discipline might have reverted to (or never emancipated from) a state of immaturity. In a chapter entitled 'Immature and ineffective fields of inquiry' Jerome R. Ravetz remarks (1971, p. 366):

> *[…] The situation becomes worse when an immature or ineffective field is enlisted in the work of resolution of some practical problem. In such an uncontrolled and perhaps uncontrollable context, where facts are few and political passions many, the relevant immature field functions to a great extent as a 'folk-science'. This is a body of accepted knowledge whose function is not to provide the basis for further advance, but to offer comfort and reassurance to some body of believers.*

Often the falsification of a frame involving dense mathematical modelling can do without the language of mathematics, but use just plain English. To make an example, a critique of the already mentioned dynamic stochastic general equilibrium models DSGE used as policy instruments (and not as theoretician tool) is possible by falsifying the underlying hypotheses of 'efficient markets' and 'representative agent' (Mirowski, 2013, pp 275-286). This is not a new approach. Translating into English the result of mathematical elaboration was a teaching of Alfred Marshall (Pigou, Ed., 1925, p. 427), a teaching which is not unknown to present day economists (Krugman, 2009, p. 9) but which is often neglected when using mathematical modelling as Latin, to obfuscate rather than to illuminate (Saltelli et al., 2013).

We stress again that we are not criticizing mathematical models *per se*, but as an input to policy, e.g. as a tool to generate inferences for policy. For Joseph Stiglitz (2011):

> *Models by their nature are like blinders. In leaving out certain things, they focus our attention on other things. They provide a frame through which we see the world.*

There is nothing wrong in using blinders in the quest for theoretical progress. Problems arise when the same tool is used to prescribe policy, expediently neglecting the blinding stage. Nassim Taleb (2007) derides this a an attempt to 'Platonify reality'. Rayner see this as one of the strategies to socially construct ignorance and calls it 'displacement':

> […] *displacement occurs when an organization engages with an issue, but substitutes management of a representation of a problem (such as a computer model) for management of the represented object or activity.*

Displacement does not imply wrong models – which could possibly be corrected, but irrelevant models, which cannot be corrected through "learning by doing" and hence can do damage for a longer period of time.

Evidence based policy has thus reached a situation of paradox, where all know and repeat that a certain practice – displacement in Rayner's lingo – is incorrect, but it is pursued nevertheless. In this way society is led to associate the stabilization of its own wellbeing with the stabilization of the institutional settings determining the status quo.

An illustration of the paradox is the deployment of mathematical modelling to predict the behaviour of complex self-organizing systems (including those that are reflexive such as human societies) and that the quality of the scientific input to the policy process is ensured by the rigour of the methods deployed. This assumption overlooks the accumulation of uncertainties which – when properly appraised – implies the total inability of these tools to generate useful inference. Thus we expect for example that modelling approaches which have failed to predict a financial and economic crisis will

be able to inform us about the behaviour of a system involving institutions, societies, economies and ecologies, such as we do when applying the craft of cost benefit analysis (CBA) to climate change, and pretend to assess the impact on the economy of increased crime rates resulting from hotter temperatures (Rhodium Group, 2014; Saltelli et al., 2015). This use of quantification will facilitate abuse and corruption. As noted by Porter (1995) this use of quantification will often be driven by a need for legitimacy by institutions in need of one:

> *The appeal of numbers is especially compelling to bureaucratic officials who lack the mandate of a popular election, or divine right. Arbitrariness and bias are the most usual grounds upon which such officials are criticized. A decision made by the numbers (or by explicit rules of some other sort) has at least the appearance of being fair and impersonal. Scientific objectivity thus provides an answer to a moral demand for impartiality and fairness. Quantification is a way of making decisions without seeming to decide. Objectivity lends authority to officials who have very little of their own.*

3. Solutions: Responsible use of quantitative information

The preceding section was focused on what should be unlearned in order to achieve progress in the use of science in support to policy. We have shown that the paradigm of evidence based policy is based on the assumption of prediction and control, which may be used to eliminate "scruples", intended as feelings of doubt or hesitation with regard to the morality or propriety of a given course of action.

What should be learned instead? What are our proposed strategies? Our suggestion is to take as a deliberate strategy the goal of reintroducing doubts and scruples in the process of deliberation, somewhat closer to Montaigne, somewhat farther from Descartes (Toulmin, 1990).

Guaranteeing the quality of the process of production and use of scientific information for governance must minimize the negative effect of hypocognition on the final choice of a policy. For this reason it is essential to study how the frame was constructed, and how this selection has cascaded into a predefined set of data, indicators and mathematical models. In this section we try advance a few suggestions to this end.

A first requirement for a better use of science for policy is a responsible use of quantitative information (EC, 2015), away from indicators rich in spurious accuracy and fantastic model-generated numbers. This requires the adoption of specific tools of quality control. For this we take epistemological inspiration from Post Normal Science (PNS, Funtowicz and Ravetz, 1991, 1992, 1993), which inspires the present special issue on FUTURES. A recent useful review of PNS is in Carrozza, (2014).

Practical tools developed in the context of PNS to address the quality of the inference feeding into policy are NUSAP and sensitivity auditing.

- NUSAP is a notational system called for the management and communication of uncertainty in science for policy, based on five categories for characterizing any quantitative statement: Numeral, Unit, Spread, Assessment and Pedigree (Funtowicz & Ravetz, 1990; van der Sluijs et al., 2005; see also http://www.nusap.net/).

- Sensitivity auditing (Saltelli et al., 2013; Saltelli and Funtowicz, 2014) extends sensitivity analysis as used in the context of mathematical modelling to settings where the models are used to produce inference for policy. Sensitivity auditing questions the broader implications of the modelling exercise, its frame, its assumptions, the assessment of the uncertainties, the transparency of the inference, the veracity of the sensitivity analysis and the legitimacy of the assessment.

Both practices are useful for taming scientific hubris. Frank H. Knight observed in 1921 that:

> *We live in a world of contradiction and paradox, a fact of which perhaps the most fundamental illustration is this: that the existence of a problem of knowledge depends on the future being different from the past, while the possibility of the solution of the problem depends on the future being like the past.*

We suggest a re-learning of Knight's warning, and a stronger reconsideration of the differences between risks, that can be computed, versus uncertainties, which cannot. Ignoring this lesson will transform us in the character of the joke where a drunkard looks for his lost key under the lamppost, even though he knows that he lost it elsewhere, only because at least under the post there is light. Nassim Nicholas Taleb calls this 'The delusion of uncertainty'. A richer taxonomy of ignorance is offered by Bryan Wynne (1992), which distinguishes:

> *RISK - Know the odds.*
> *UNCERTAINTY - Don't know the odds: may know the main parameters. May reduce uncertainty but increase ignorance.*
> *IGNORANCE - Don't know what we don't know. Ignorance increases with increased commitments based on given knowledge.*
> *INDETERMINACY - Causal chains or networks open.*

For Wynne:

> *Science can define a risk, or uncertainties, only by artificially 'freezing' a surrounding context which may or may not be this way in real-life situations. The resultant knowledge is therefore conditional knowledge, depending on whether these pre-analytical assumptions might turn out to be valid. But this question is indeterminate - for example, will the high quality of maintenance, inspection, operation, etc., of a risky technology be sustained in future, multiplied over replications, possibly many all over the world?*

The taming of scientific hubris is at the basis of a more effective use of science for governance. We suggest thus moving beyond 'evidence based policy' toward 'robust policy', based on a strategy of filtering of potential policies in a context of falsification. We call this 'robust policy' borrowing from Helga Nowotny's (2003) concept of socially robust knowledge: a kind of knowledge that has been filtered through the lenses of different stakeholders and normative stances.

The suggested strategy involves a quality check on proposed policies and narratives on governance using the method of falsification with respect to:

- feasibility (compatibility with external constraints),
- viability (compatibility with internal constraints) and
- desirability (compatibility with normative values adopted in the given society).

If the policy will result unfeasible or unviable or undesirable in relation to one of the quality checks we would have individuated either a bottleneck or a political issue or a true impossibility to be dealt with. Instead of prediction and control leading to planning and optimization, one should rather focus on strategic learning through falsification leading to flexible management.

This approach has elements of similarity with the strategy suggested by Rayner (2012) to overcome socially constructed ignorance: the idea of 'clumsy solutions'. While socially constructed ignorance helps to keep 'uncomfortable knowledge' at bay, clumsy solutions allow it to be processed:

> *Clumsy solutions may emerge from complex processes of both explicit and implicit negotiation. In other words, solutions are clumsy when those implementing them converge on or accept a common course of action for different reasons or on the basis of unshared epistemological or ethical principles* […] *They are inherently satisficing* […] *rather than optimizing approaches, since each of the competing solutions is optimal from the standpoint of the proposer. Clumsy solutions are inherently pluralistic* […]

Clumsy solutions resonate with the 'working deliberatively within imperfections' (van der Sluijs et al., 2008) of the Post Normal Science's extended participation model, and with the 'rediscovery of ignorance' advocated by Ravetz (2015, p. xviii).

A key step in the identification of the feasibility, viability and desirability domains entails looking through different lens – i.e. dimensions and scales of analysis. This strategy for sustainability analysis is detailed in (Giampietro et al. 2013; 2014).

An example of this strategy can be made on food security:

- When checking the feasibility of food security against external constraints (context/black-box - agriculture) we have to measure requirements and supply in terms of kg of potatoes, vegetables and animal products.

- However, if we want to check the viability of food security in relation to internal constraints (black box/internal parts – human diet) we have to measure requirements and supply in terms of kcal of carbohydrates, proteins and fats.

In the same way for energy security:

- When checking the feasibility of energy security against external constraints (context/black-box - "primary energy sources") we have to measure relevant physical quantities in terms of tons of coal, kinetic energy of falling water, cubic meters of natural gas,
- If we want to check the viability in relation to internal constraints (black box/internal parts - "energy carriers") we have to measure relevant quantities in terms of kWh of electricity, MJ of fuels.

Quantitative representations useful to study *feasibility* are not equivalent to quantitative representations useful to study *viability* and the information given by these two typologies of representations cannot be used to study *desirability* without involving in the discussion those social actors carrying legitimate but contrasting normative values (Giampietro et al. 2006).

Having operationalized the definition of these three domains it becomes possible to carry out an informed deliberation for evaluating policies having the goal of balancing efficiency with adaptability in view of sustainability. This may possibly feed into a multi-criteria characterization of the proposed solutions with respect to the different normative ingredients (Munda, 2008).

The proposed approach is equivalent to exploring a multi-dimensional space with a parsimonious and appropriate experimental design, instead of concentrating an unrealistic degree of detail around a single point in this space. We may call this procedure of widening of the set of available frame 'Quantitative story-telling for governance'. QST may assist to generate plausible and relevant stories capable of reducing hypocognition in the chosen issue definition/problem structuring – a strategy also suggested by 'cognitive activist' George Lakoff (2014).

Quantitative story telling has the goal of guaranteeing the quality of the chosen story-telling in the given socio-economic and ecological context. QST is specially designed to copy with relevant "known knowns" and "known unknowns", while being mindful of the unavoidable presence of "unknown unknowns". The fitness of different policy options can then be gauged from the integration of a robust mix of relevant narratives, plausible explanations and pertinent perceptions.

This qualitative check of the coherence of the quantitative information generated by non-equivalent models is essential. Models are by-products of the pre-analytical choice of how to represent relevant causal relations and data are by-products of the pre-analytical choice of relevant perceptions. Confronted with numbers coming from several non-equivalent descriptive domains (logically incoherent quantitative representations) one can no longer rely on big data and sophisticated algorithms. Without a quality check on the chosen story-telling more data and larger models developed within arbitrarily constrained explanations and perceptions will only increase the level of indeterminacy and uncertainty of the results.

The usefulness of the chosen stories needs to be validated using quantitative analysis that must remain coherent across scales and dimensions – i.e. a multi-scale integrated analysis of the functioning of socio-ecological systems, inclusive of their level of openness, e.g. to trade relationships, lest relevant aspects of the problems are simply externalized.

In his 'plea for reasonableness versus rationality' Stephen Toulmin (1990, 2001) contrasts the ideal of Renaissance Humanism against the Renaissance scientific revolution, which he considers as a counter-Renaissance, where Descartes' certainties replace the doubts of Montaigne. In order to return to reason, he warns, we need to 'do the right sums' more than we need to 'do the sums right' (2001, p.66). This implies a careful selection of the stories to be told before indicators are built, data collected and models run. We need to explore more frames as opposed to selecting just one and filling it with numbers.

We can illustrate this with the persisting controversy surrounding the use of genetically modified organism, a quintessential wicked issue.

The journal 'The Economist', discussing a GMO labelling scheme in Vermont (US) commented recently (2014):

> *Montpelier is America's only McDonald's-free state capital. A fitting place, then, for a law designed to satisfy the unfounded fears of foodies* […] *genetically modified crops, declared safe by the scientific establishment, but reviled as Frankenfoods by the Subarus-and-sandals set.*

For those unfamiliar with this kind of jargon, Frankenfood is GMO based food as defined by its opponents, while the *Subarus-and-sandals* set is an The Economist's own synecdoche to allude to those in Vermont who support a labelling scheme for GMO-containing food. The image accompanying the piece shows a hippy-looking public protesting against GMO. We use this as a vivid illustration of what any reader knows: opposition to GMO food is normally portrayed as a Luddite, anti-science position, and this because GMOs are treated as a nutritional 'risk to health issue'. Against this irrational position science has 'spoken' by declaring GMO's safe for human consumption, thus modern societies should by law permit (or even force, in the name of progress) their production and consumption.

This frame clashes against the reality of citizens' true concern, as measured e.g.by Marris et al., (2001). In the list of citizens' concerns gathered through participatory processes, the issue of food safety seems to be conspicuously absent, whereas a complete different set of crucial questions are asked instead:

- *Why do we need GMOs? What are the benefits?*
- *Who will benefit from their use?*
- *Who decided that they should be developed and how?*
- *Why were we not better informed about their use in our food, before their arrival on the market?*
- *Why are we not given an effective choice about whether or not to buy and consume these products?*
- *Do regulatory authorities have sufficient powers and resources to effectively counter-balance large companies who wish to develop these products?*

The variety of frames revealed by these concerns reveals that the prevailing frame 'safe GMO food versus recalcitrant citizens' is "irrelevant" for the decision to be taken when considering the concerns expressed by the citizens.

4. Conclusion

In conclusion we have argued that the evidence based policy paradigm should be revised because in its current use it deploys science to reinforce hypocognition. We have likewise argued that evidence based policy cannot be separated by policy based evidence. The accumulation of data, indicators and mathematical modelling in support to a given frozen framing of an issue obfuscates and distracts from the important task which is the semantic opening of the frame. A quantitative problem structuring may empower those that have selected the given story-telling to eliminate, through induced hypocognition, uncomfortable knowledge. Spurious precision and disproportionate mathematics deter the use of plain English to question the premises of an analysis.

Shared normative values (frames) are the result of negotiation and shifting of power relations (Lakoff, 2014). This implies that even those story-tellings, strategies, and narratives that resulted useful for guiding human action in a given historic period may become useless (and therefore potentially dangerous as misleading) when the meanings they assign to the terms "feasibility", "viability" and "desirability" in relation to the stated goals has changed. We suggest that quantitative story telling as described in the present work may represent a socially robust alternative to the present style of quantitative analysis in evidence based policy.

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