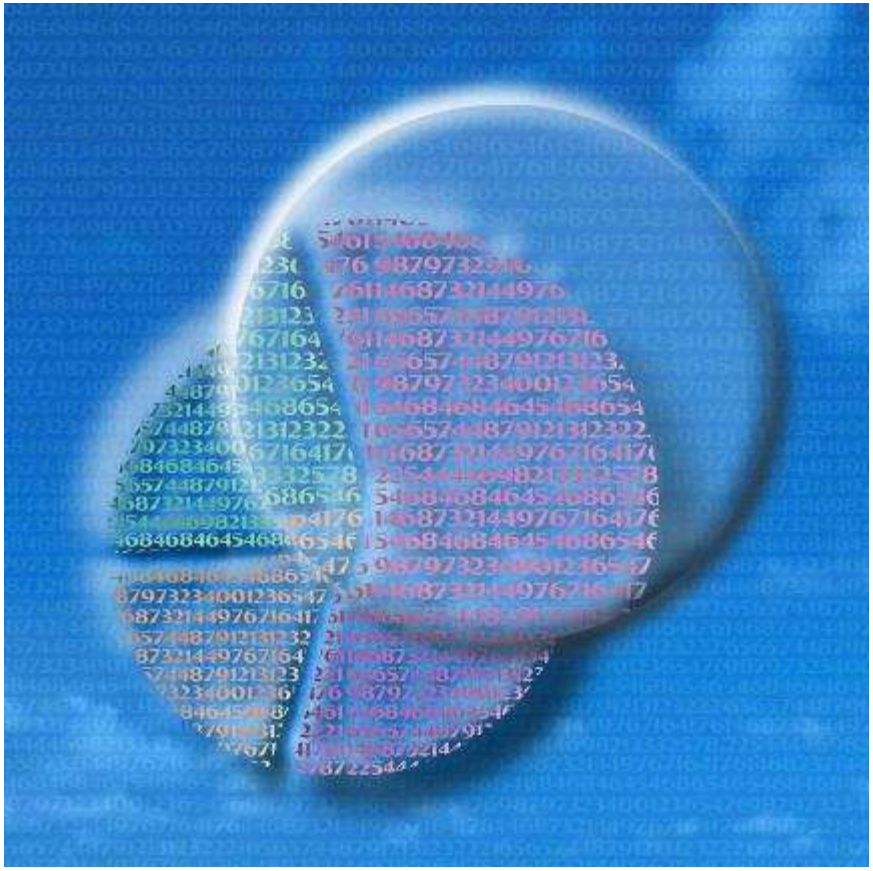

Sensitivity Auditing+

Andrea Saltelli

Centre for the Study of the Sciences and the Humanities (SVT), University of Bergen & Open Evidence Research, Universitat Oberta de Catalunya

Water scenario & modelling narratives. Moving towards Quality narratives in Water policy
February 26th – 27th, JRC, Ispra

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Tweets by @AndreaSalte

andrea saltelli
@AndreaSaltelli

Replying to @AndreaSaltelli

This is how my lesson starts - criticizing the Trump against Enlightenment antinomy. The book of Pinker makes this discussion urgent.
newstatesman.com/culture/books/...

"Trump seems to reject the concepts of objective truth, rational discourse, and scientific expertise, the Enlightenment ideals on which this country was founded."

1h

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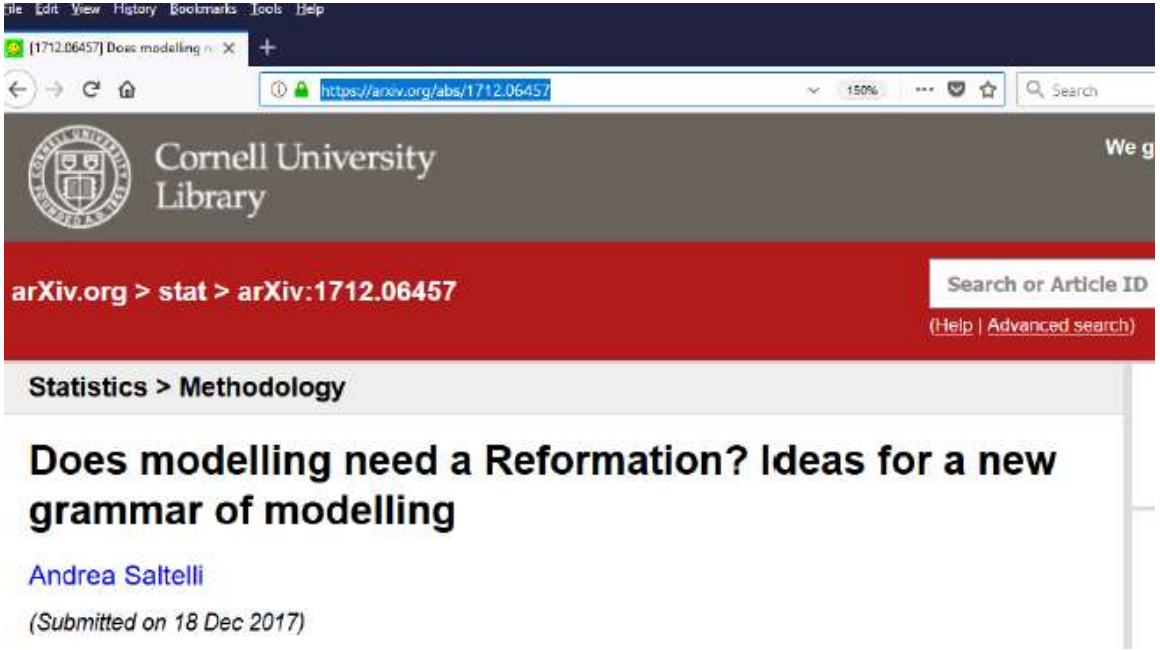
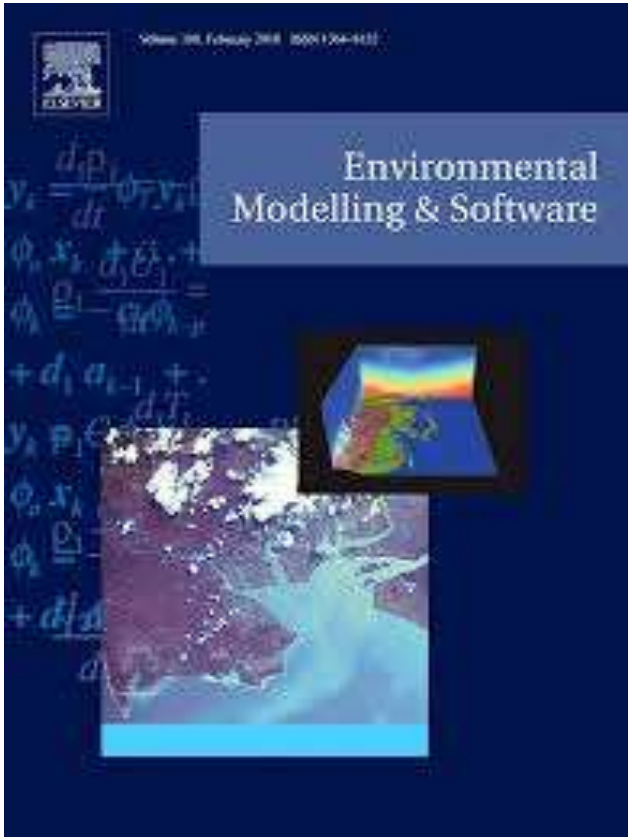
➔ more material on www.andreasaltelli.eu

Recipes for diligent quantification

A new grammar for modelling





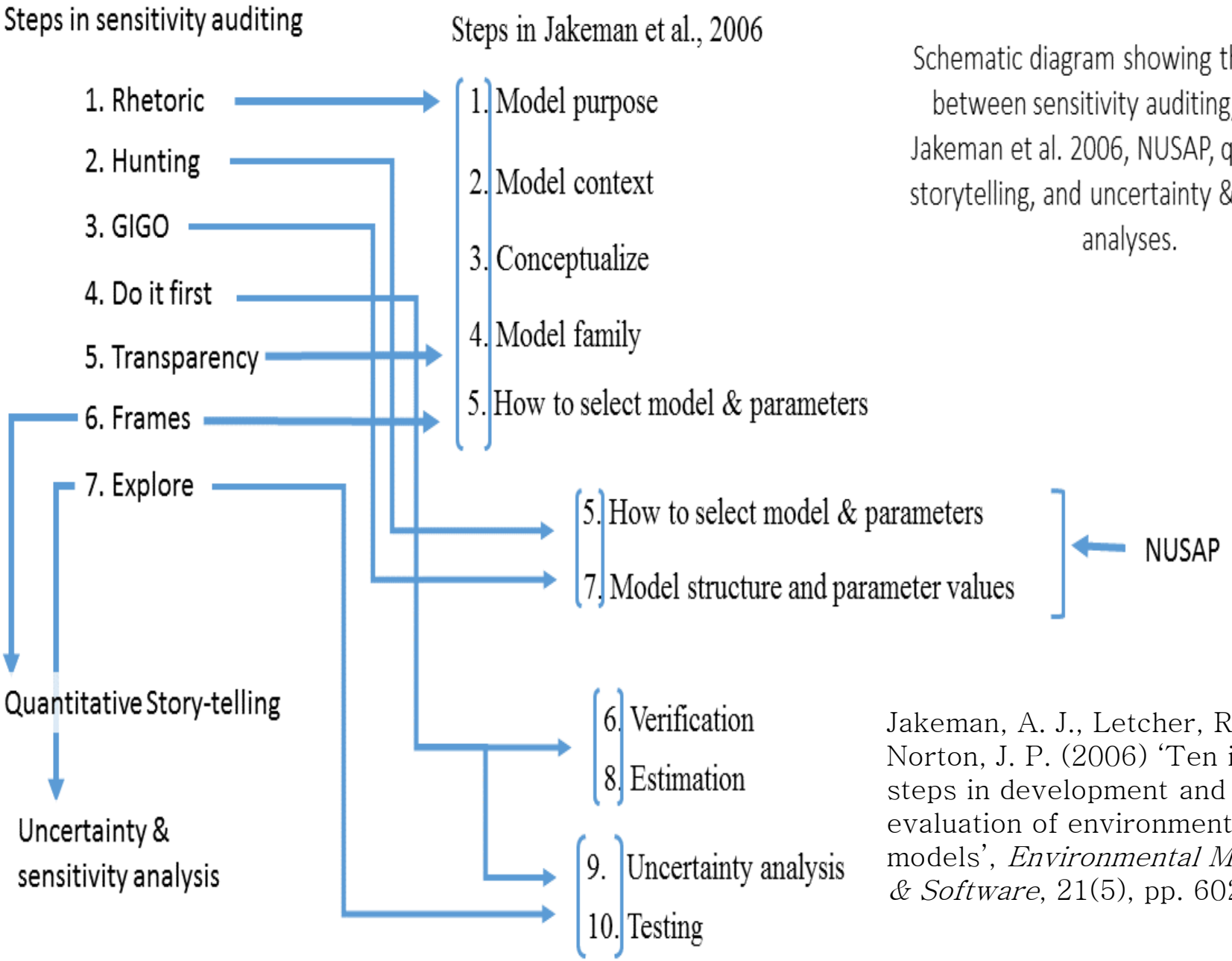
The quality of mathematical modelling versus:

Quality of statistical modelling; Science's own quality control crisis in medicine, economics, psychology, forensics, nutrition; Sociology of quantification, ethics of algorithm …

Reformation and new grammar for modelling

Quantitative methodologies UA and SA as bedrock

Sensitivity auditing, quantitative storytelling, and ethics of quantification.



Schematic diagram showing the linkages between sensitivity auditing, steps in Jakeman et al. 2006, NUSAP, quantitative storytelling, and uncertainty & sensitivity analyses.

Jakeman, A. J., Letcher, R. A. and Norton, J. P. (2006) 'Ten iterative steps in development and evaluation of environmental models', *Environmental Modelling & Software*, 21(5), pp. 602–614.

Sensitivity analysis

Saltelli, A., Annoni, P., 2010, How to avoid a perfunctory sensitivity analysis, Environmental Modeling and Software, 25, 1508-1517.

Sensitivity auditing

Saltelli, A., Guimarães Pereira, Â., Van der Sluijs, J.P. and Funtowicz, S., 2013, 'What do I make of your latinorum? Sensitivity auditing of mathematical modelling', Int. J. Foresight and Innovation Policy, (9), 2/3/4, 213–234.

Quantitative storytelling

Saltelli, A., Giampietro, M., 2017, What is wrong with evidence based policy, and how can it be improved? Futures, 91, 62-71.

A new grammar

Saltelli, A., Does Modelling need a reformation? Ideas for a new grammar of modellinf, on ArXiv

Futures 91 (2017) 5–11

Contents lists available at ScienceDirect

Futures

journal homepage: www.elsevier.com/locate/futures

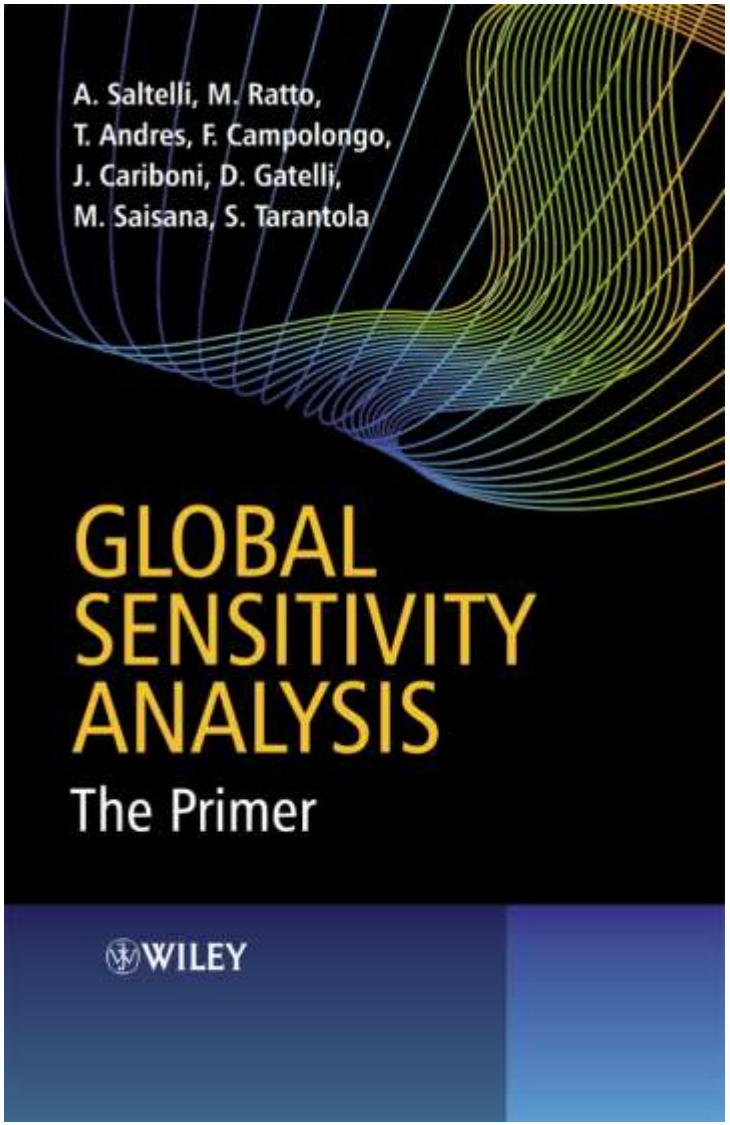
What is science's crisis really about?

Andrea Saltelli[a,b,*], Silvio Funtowicz[a]

[a] Centre for the Study of the Sciences and the Humanities (SVT), University of Bergen, Norway
[b] Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona, Spain

Sensitivity analysis

Sensitivity analysis book available on LibGen



http://ec.europa.eu/smart-regulation/

Source: IA Toolbox, p. 391

EUROPEAN COMMISSION

Better Regulation "Toolbox"

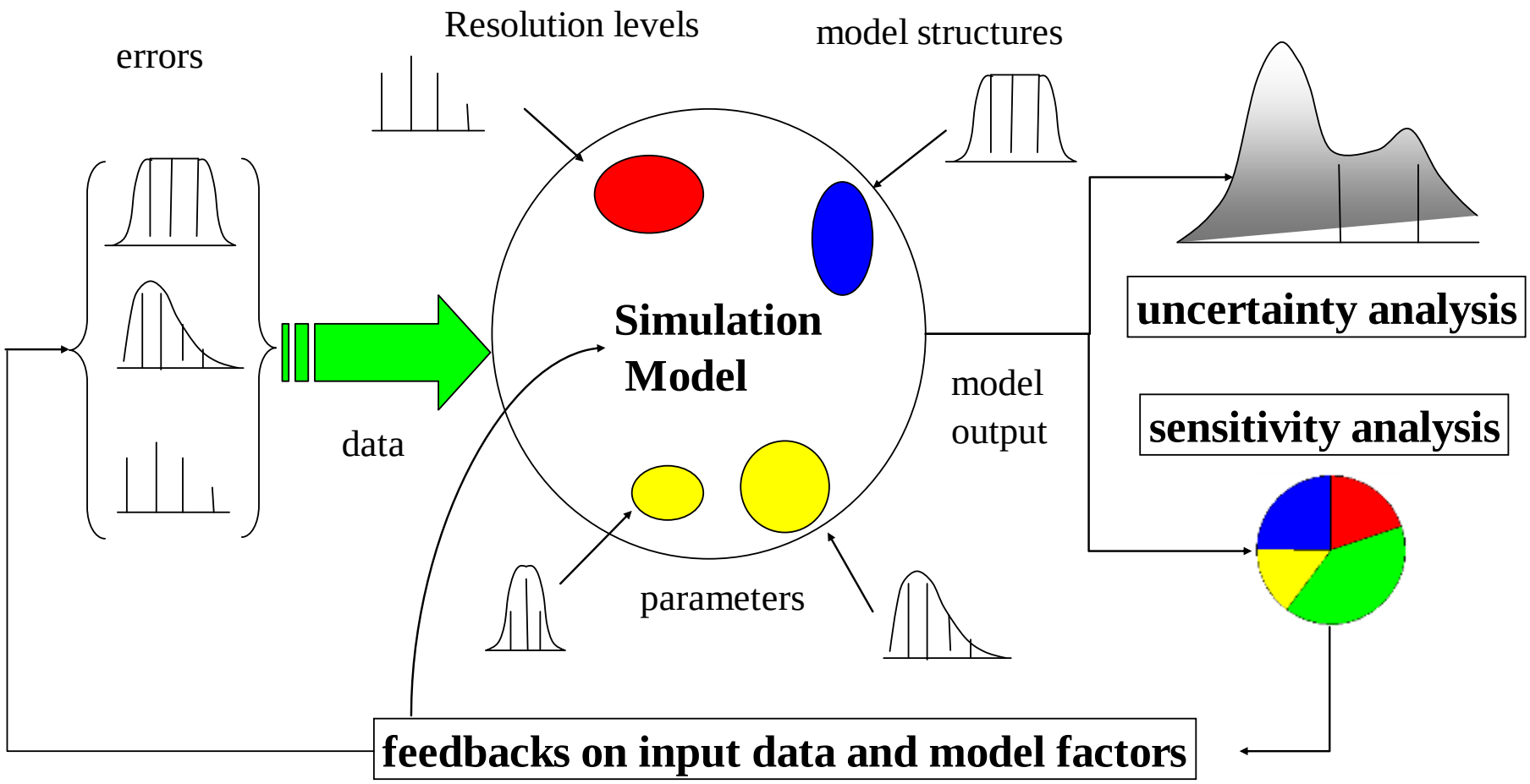
4. SENSITIVITY AND UNCERTAINTY ANALYSES

Page 391

Six steps for a global SA:

1. Select one output of interest;
2. Participatory step: discuss which input may matter;
3. Participatory step: (extended peer review) define distributions;
4. Sample from the distributions;
5. Run (=evaluate) the model for the sampled values;
6. Obtain in this way both the uncertainty of the prediction and the relative importance of variables.

An engineer's vision of UA, SA



One can sample more than just factors

One can sample modelling assumptions, alternative data sets, resolution levels…

Secrets of sensitivity analysis

First secret: The most important question is the question.

Corollary 1: Sensitivity analysis is not "run" on a model but on a model once applied to a question

First secret: The most important question is the question.

Corollary 2: The best setting for a sensitivity analysis is '*via negativa*'

It is better to be in a setting of falsification than in one of confirmation (Oreskes et al., 1994)

[Normally the opposite is the case]

Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences, Naomi Oreskes, Kristin Shrader-Frechette, Kenneth Belitz, Science, New Series, Vol. 263, No. 5147 (Feb. 4, 1994), pp. 641-646.

Second secret: Sensitivity analysis should not be used to hide assumptions [it often is]

Third secret: If sensitivity analysis shows that a question cannot be answered by the model one should find another question or model

[Often the love for one's own model prevails]

Badly kept secret:

There is always one more bug!

(Lubarsky's Law of Cybernetic Entomology)

And of course please don't …

… run a sensitivity analysis where each factors has a 5% uncertainty

Sensitivity auditing

EC impact assessment guidelines: what do they say about sensitivity auditing ?

http://ec.europa.eu/smart-regulation/guidelines/docs/br_toolbox_en.pdf

p. 392

… where there is a major disagreement among stakeholders about the nature of the problem, … then sensitivity auditing is more suitable but sensitivity analysis is still advisable as one of the steps of sensitivity auditing.

p. 393

Sensitivity auditing, [...] is a wider consideration of the effect of all types of uncertainty, including structural assumptions embedded in the model, and subjective decisions taken in the framing of the problem.
[...]
The ultimate aim is to communicate openly and honestly the extent to which particular models can be used to support policy decisions and what their limitations are.

p. 393

“In general sensitivity auditing stresses the idea of honestly communicating the extent to which model results can be trusted, taking into account as much as possible all forms of potential uncertainty, and to anticipate criticism by third parties.”

The rules of sensitivity auditing

Rule 1: Check against rhetorical use of mathematical modelling;

Rule 2: Adopt an "assumption hunting" attitude; focus on unearthing possibly implicit assumptions;

Rule 3: Check if uncertainty been instrumentally inflated or deflated.

The rules of sensitivity auditing

Rule 4: Find sensitive assumptions before these find you; do your SA before publishing;

Rule 5: Aim for transparency; Show all the data;

Rule 6: Do the right sums, not just the sums right; the analysis should not solve the wrong problem;

Rule 7: Perform a proper global sensitivity analysis.

Quantitative story-telling

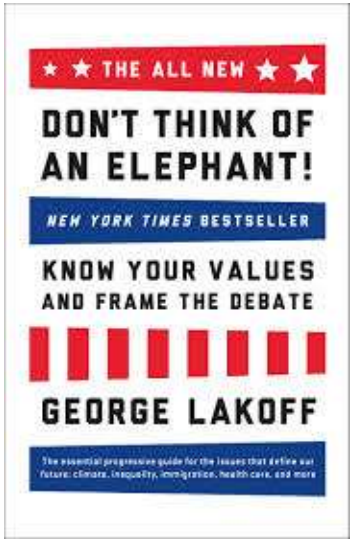
“There is only a perspective seeing, only a perspective “knowing”; and the more affects we allow to speak about one thing, the more eyes, different eyes, we can use to observe one thing, the more complete will our “concept” of this thing, our “objectivity”, be.”

Friedrich Nietzsche, Genealogy of Morals, Third Essay.

Frames

The expression ‘tax relief’ is apparently innocuous but it suggests that tax is a burden, as opposed to what pays for road, hospitals, education and other infrastructures of modern life (Lakoff, 2004)

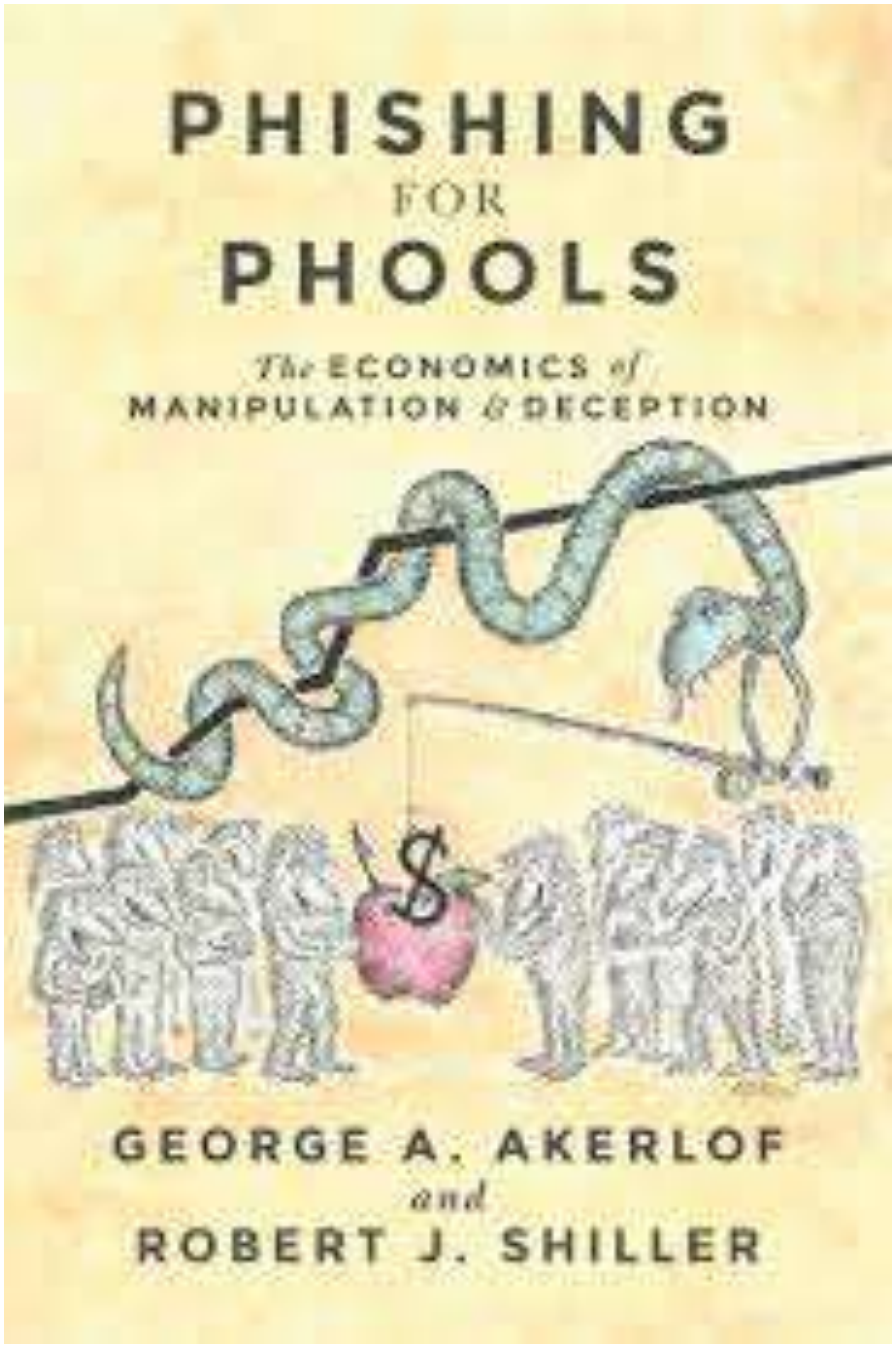
George Lakoff



Lakoff, G., 2010, Why it Matters How We Frame the Environment, Environmental Communication: A Journal of Nature and Culture, 4:1, 70-81.

Lakoff, G., 2004-2014, Don’t think of an elephant: know your values and frame the debate, Chelsea Green Publishing.

Frames


PHISHING
FOR
PHOOLS
The ECONOMICS of
MANIPULATION & DECEPTION
$
GEORGE A. AKERLOF
and
ROBERT J. SHILLER

Frames

For Akerlof and Shiller – against what the 'invisible hand' would contend – economic actors have no choice but to exploit frames to 'phish' people into practices which benefit the actors not the subject phished.

George Akerlof

Robert R. Shiller

QST tests frames/narratives for:

- Misconstruction, internal contradictions, technical errors
- Feasibility (compatibility with processes outside human control);
- Viability (compatibility with processes under human control, in relation to both the economic and technical dimensions); and
- Desirability (compatibility with a multitude of normative considerations relevant to a plurality of actors).

Frames as hypocognition & Socially constructed ignorance

For Rayner (2012) “Sense-making [and] story-telling are possible only because of the mass of detail that we leave out.

Knowledge is possible only through the ‘social construction of ignorance’ (Ravetz, 1986)”

Steve Rayner

Jerry Ravetz

Ravetz, J., R., 1987, Usable Knowledge, Usable Ignorance, Incomplete Science with Policy Implications, Knowledge: Creation, Diffusion, Utilization, 9(1), 87-116.

Rayner, S., 2012, Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses, Economy and Society, 41:1, 107-125.

Rayner's (2012) strategies societies may use to deal with "uncomfortable knowledge".

- Denial: "There isn't a problem"
- Dismissal: "It's a minor problem"
- Diversion: "Yes I am working on it" (In fact I am working on something else)
- Displacement: "Yes and the model we have developed tells us that progress is being achieved" (The focus in now the model not the problem).

Rayner, S., 2012, Uncomfortable knowledge: the social construction of ignorance in science and environmental policy discourses, Economy and Society, 41:1, 107-125.

Denial, diversion & displacement: a science war against trump, against post truth,

January 27, 2017

To tackle the post-truth world, science must reform itself

Andrea Saltelli, *University of Bergen* and Silvio Oscar Funtowicz, *University of Bergen*

Scientists must bear some responsibility for the post-truth era and the current crisis in democracy.

November 16, 2016

Science wars in the age of Donald Trump

Andrea Saltelli, *University of Bergen* and Silvio Oscar Funtowicz, *University of Bergen*

Is the election of Donald Trump going to reignite a futile war between science and anti-science?

… marches for science and persistent scientism.

May 12, 2017

Forcing consensus is bad for science and society

Andrea Saltelli, *University of Bergen*; Mario Giampietro, *Universitat Autònoma de Barcelona*, and Tiziano Gomiero, *Masaryk University*

Insisting that science has a monopoly on the truth invalidates dissent and undermines what should be an open dialogue between science and society.

March 8, 2017

A scientists' march on Washington is a bad idea – here's why

Andrea Saltelli, *University of Bergen*

Trump is not science's biggest problem.

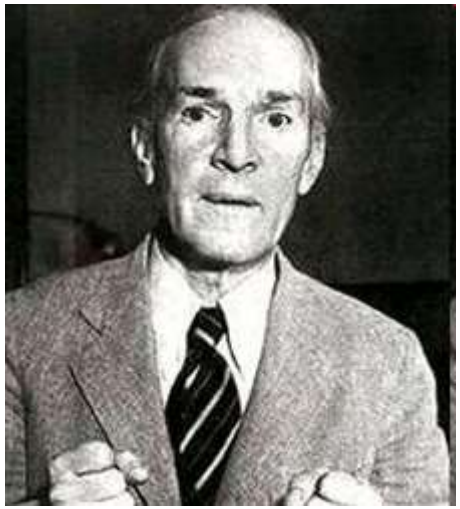
“Uncomfortable knowledge” can be used as a gauge of an institution’s health.

The larger the “uncomfortable knowledge” an institution needs to maintain, the closer it is to its ancient régime stage (Funtowicz and Ravetz, 1994).

Funtowicz, S.O. and Jerome R. Ravetz, 1994, Emergent complex systems, Futures, 26(6), 568-582.

Why frames ‘stick’

“If is difficult to get a man to understand something when his salary depends upon his not understanding it.”



Upton Sinclair

Some examples:

Sensitivity analysis: the case of the Stern review

Global Environmental Change 20 (2010) 298–302

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Sensitivity analysis didn't help. A practitioner's critique of the Stern review

Andrea Saltelli *, Beatrice D'Hombres

Joint Research Centre, Institute for the Protection and Security of the Citizen, Ispra, Italy

The case of Stern's Review – Technical Annex to postscript

Nicholas Stern, London School of Economics

William Nordhaus, University of Yale

Stern, N., Stern Review on the Economics of Climate Change. UK Government Economic Service, London, www.sternreview.org.uk.

Nordhaus W., Critical Assumptions in the Stern Review on Climate Change, SCIENCE, 317, 201-202, (2007).

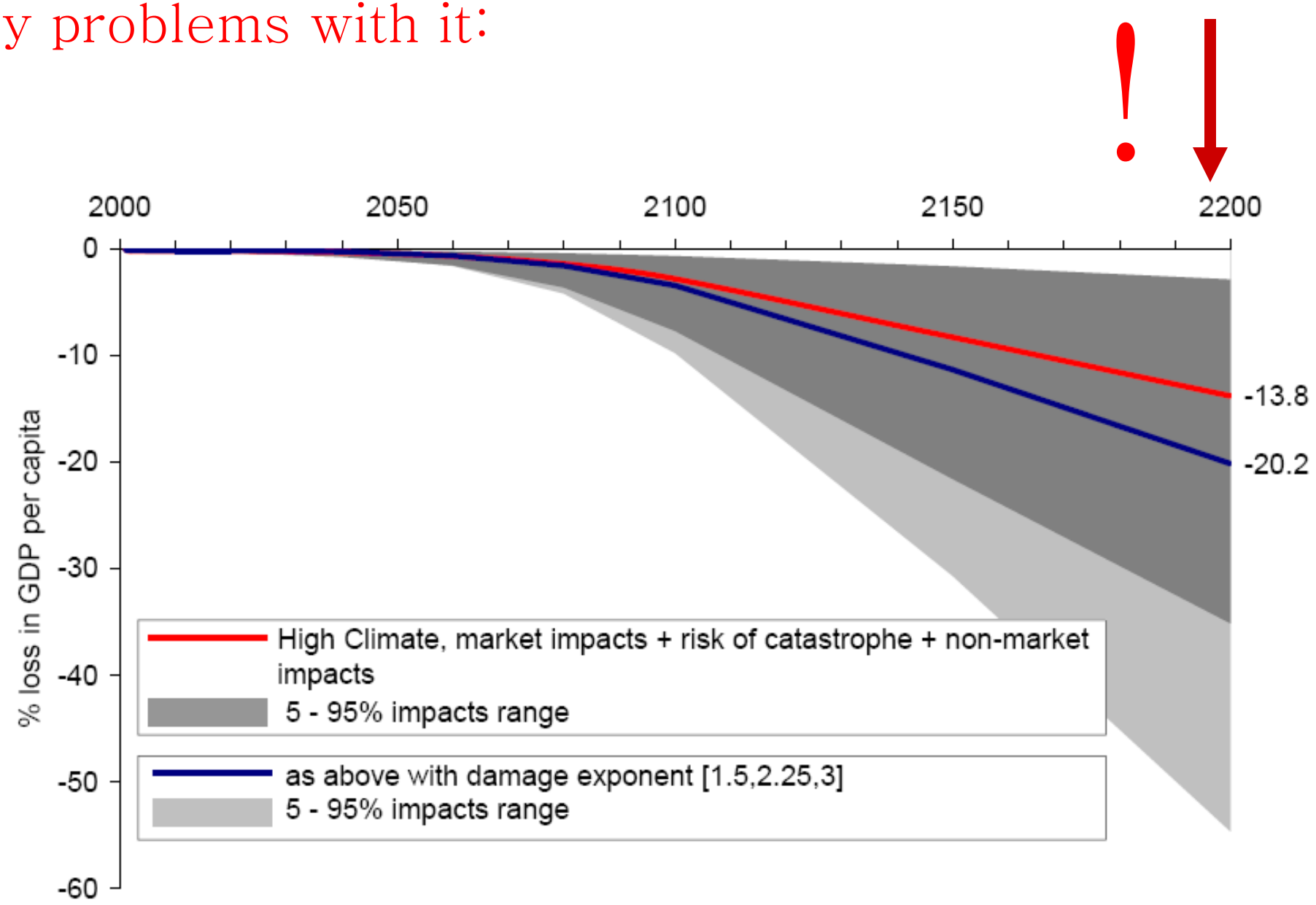
The Stern – Nordhaus exchange on *SCIENCE*

1) Nordhaus falsifies Stern based on 'wrong' range of discount rate

2) Stern's complements its review with a postscript: a sensitivity analysis of the cost benefit analysis

3) Stern thus says: My analysis shows robustness'

My problems with it:

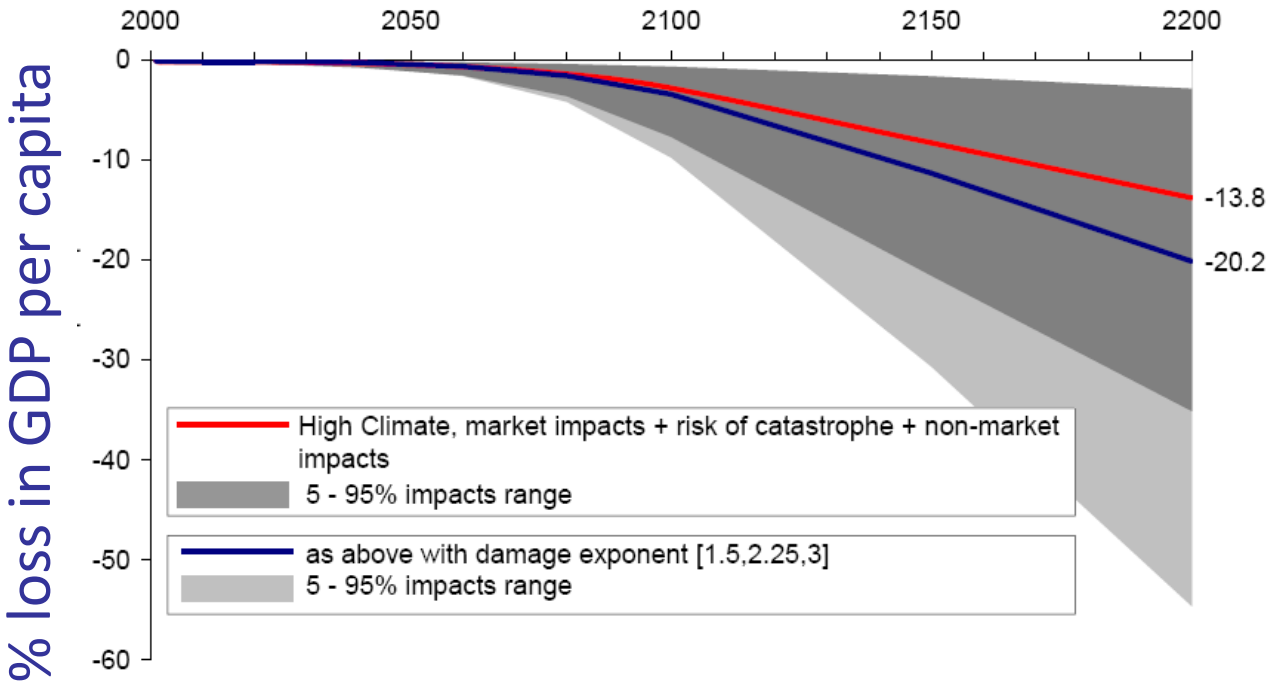


… but foremost Stern says:

changing assumptions → important effect

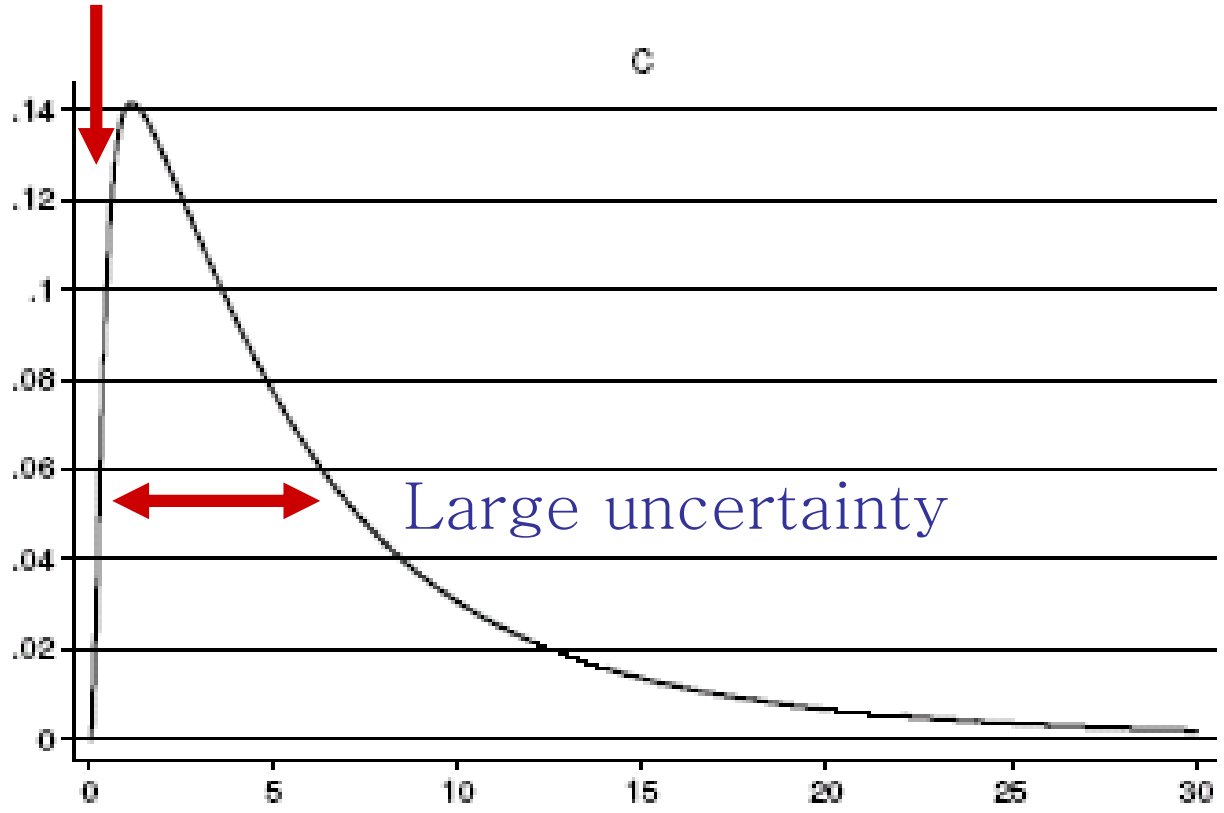
when instead he should admit that:

changing assumptions → all changes a lot



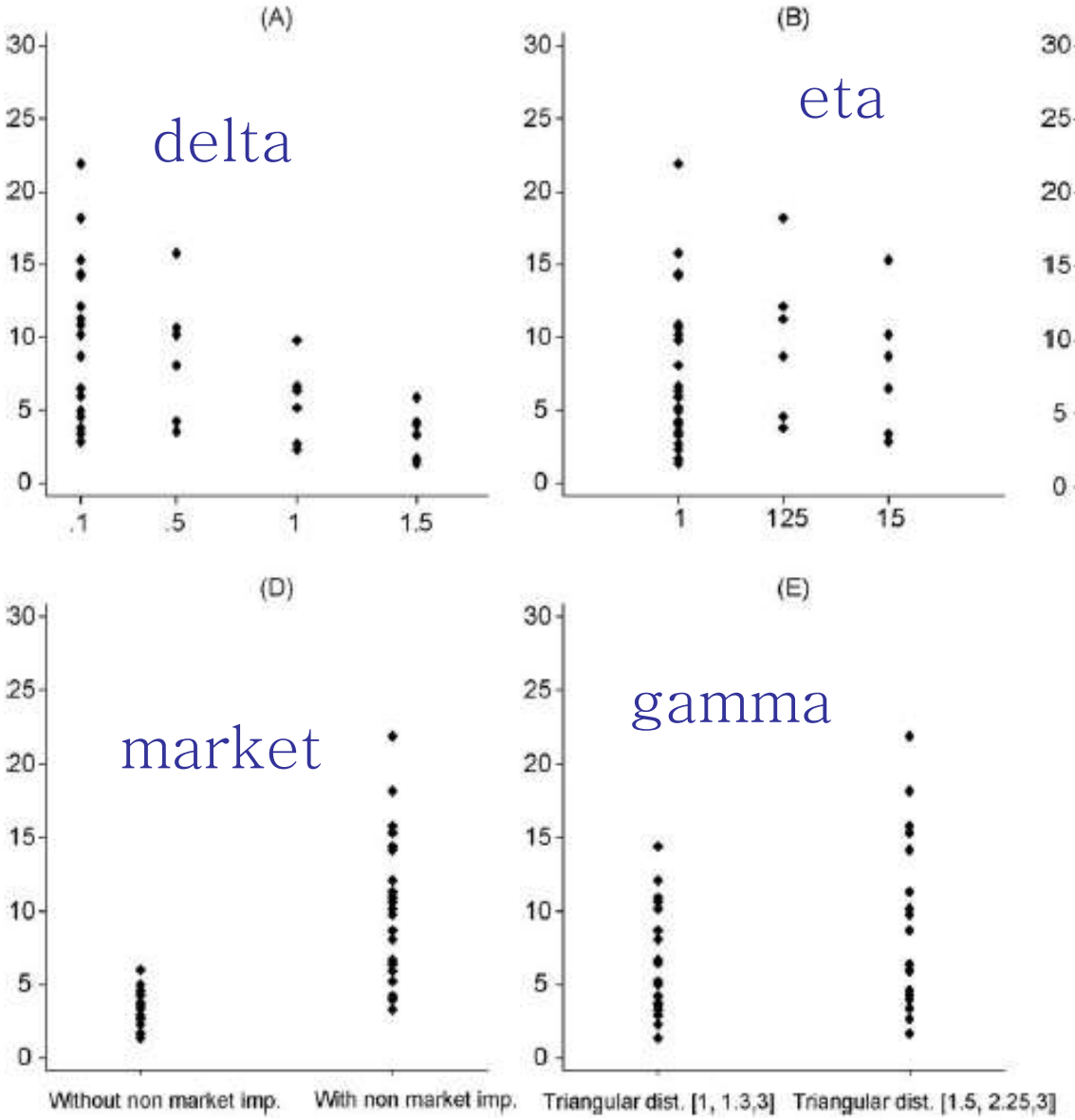
How was it done? A reverse engineering of the analysis

Missing points

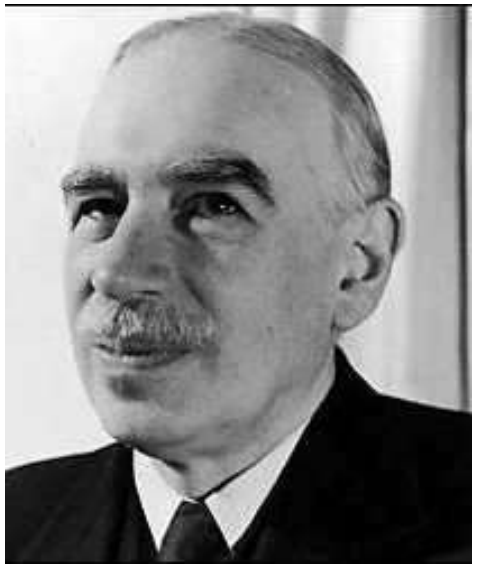


% loss in GDP per capita

Sensitivity analysis here (also by reverse engineering)



Same criticism applies to Nordhaus – both authors frame the debate around numbers which are …



… precisely wrong

Some examples:
Sensitivity auditing: the OECD PISA study

Do PISA data justify PISA-based education policy?

With Luisa Araújo and Sylke V. Schnepf

International Journal of Comparative Education and Development
Vol. 19 No. 1, 2017
pp. 1-17

2396-7404
DOI 10.1108/IJCED-12-2016-0023

THE CONVERSATION

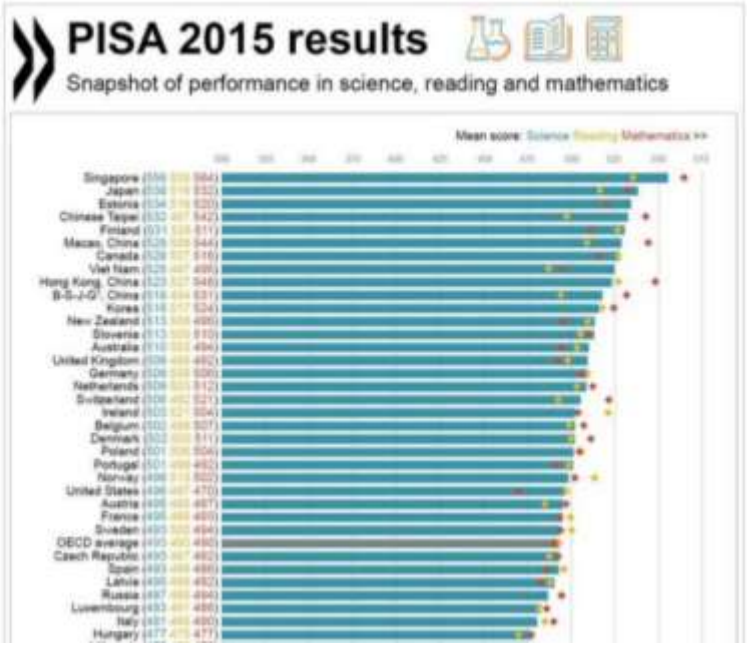
Academic rigour, journalistic flair

Arts + Culture | Business + Economy | Cities | Education | Environment + Energy | FactCheck | Health + Medicine | Politics + Society | Science + Technology

International PISA tests show how evidence-based policy can go wrong

June 12, 2017 3.55pm AEST

Chemistry class at the Dong Tien Secondary School, Thai Nguyen Province, Vietnam. Asian Development Bank/flickr, CC BY-SA



A condensed version of the article

With PISA the OECD gained the centre-stage in the international arena on education policies, which led to important controversies

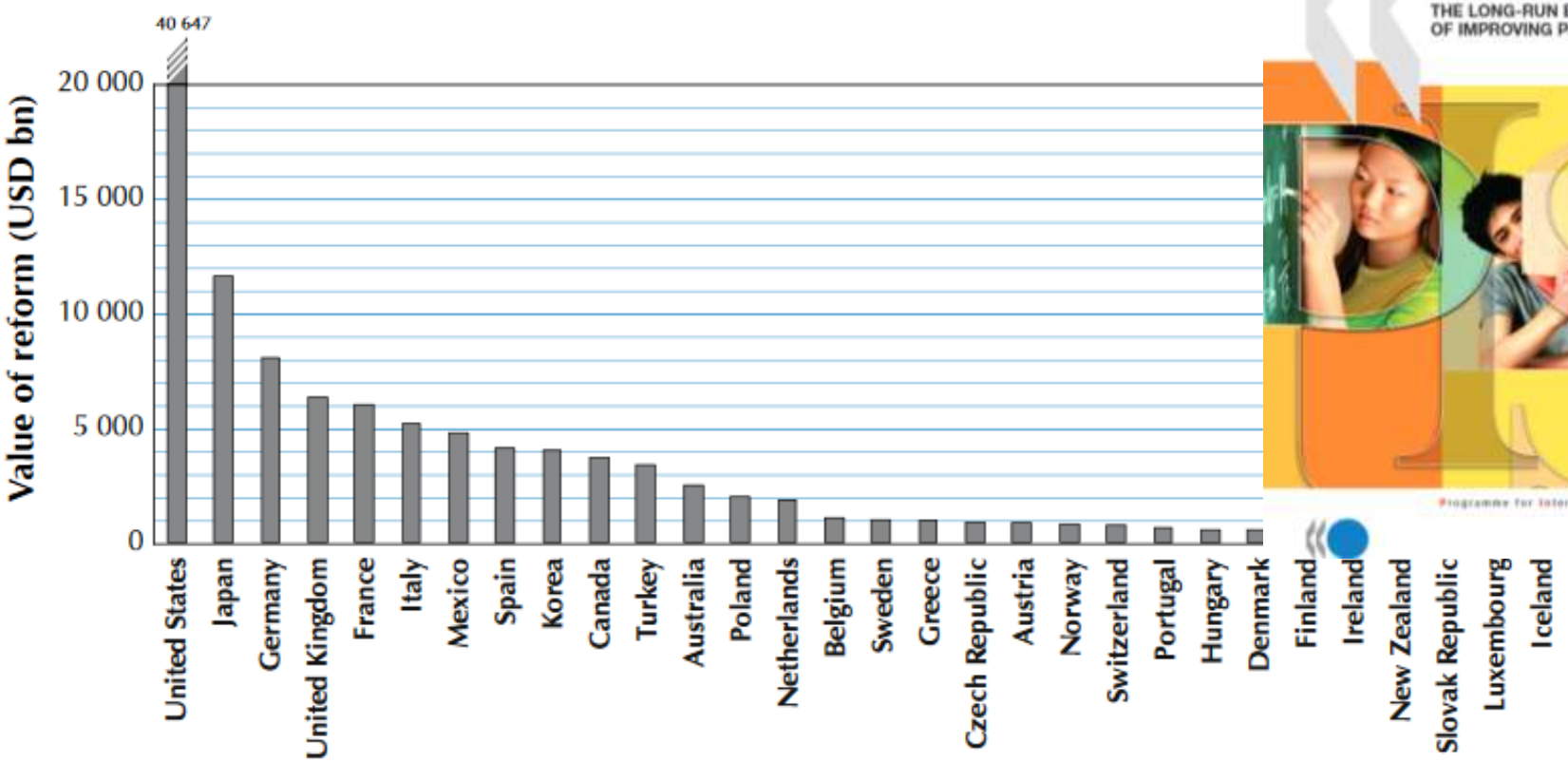
http://www.theguardian.com/education/2014/may/06/oecd-pisa-tests-damaging-education-academics

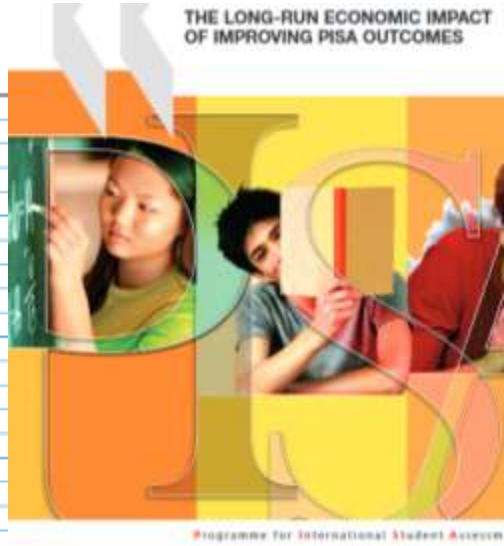
Critical remarks by the 80 signatories of the letter:

- Flattening of curricula (exclusion of subjects)
- Short-termism (teaching to the test)
- Promoting “life skills to function in knowledge societies”
- Stressing the student
- … ➔ Stop the test!
- A more participatory run of the study would be advisable

Figure 1

Present value of Scenario I (improve student performance in each country by 25 points on the PISA scale) in billion USD (PPP)





Note: Discounted value of future increases in GDP until 2090 due to reforms that improve student performance in each

http://www.oecd.org/edu/school/programmeforinternationalstudentassessmentpisa/thehighcostofloweducationalperformance.htm

PISA's daring quantifications:

"If every EU Member State achieved an improvement of 25 points in its PISA score as Germany and Poland did over the last decade, the GDP of the whole EU would increase by between 4% and 6% by 2090;

such an 6% increase would correspond to 35 trillion Euro"

Woessmann, L. (2014), "The economic case for education", EENEE Analytical Report 20, European
Expert Network on Economics of Education (EENEE), Institute and University of Munich.

We find both technical and normative issues:

1) Non response bias (which students are excluded; PISA non-response for England: the bias turned out to be twice the size of the OECD declared standard error in 2003

2) Non open data, which makes SA impossible

3) Flattening curricula (do all countries wish to prosper by becoming knowledge societies?)

4) Power implications: power in the use of evidence. OECD (unelected officers and scholars) becoming a global super-ministry of education

Some examples:

Sensitivity auditing/Quantitative storytelling: scenarios for food security

Food ethics (2017) 1:173–179
DOI 10.1007/s41055-017-0020-6

DISCUSSION PAPER

Problematic Quantifications: a Critical Appraisal of Scenario Making for a Global 'Sustainable' Food Production

Andrea Saltelli[1,2,3] · **Samuele Lo Piano**[1]

Accepted: 4 August 2017 / Published online: 15 August 2017

"What follows is a hypothetical executive summary from an imagined Food and Agriculture Organization (FAO) report on the state of the world's food systems, written from the perspective of the 2050s"

https://www.thesolutionsjournal.com/article/pathways-leading-sustainable-healthy-global-food-system/

Executive Summary: FAO State of World Agriculture in 2050 Draft Report

"[…]this FAO report presents evidence that the international food system of the second half of the 21st century is more sustainable than the food system of the late 20th or early 21st centuries.

[…] today more people are being fed on less land and agriculture is requiring fewer inputs"

Executive Summary: FAO State of World Agriculture in 2050 Draft Report

Three digits

"[…] despite there being 10 billion people on the planet, today agriculture requires 438 million hectares* less land than it did in 2015, yet produces more adequate nutrition for all."

*Authors' estimate

This [438 Mha] figure was arrived at by assuming that:

- Agriculture shifts away from over production of cereals, oils, and sugars, but increases fruit and vegetables;
- Agricultural yields increase ~1%/y between now and 2050.
- Protein consumption shifts from 86% animals and 14% plants to 50% animal and 50% plant.

"Please contact the authors for references etc. pertaining to these calculations"

Our study:

- Gain in number of hectares: three significant digits (438 millions)?

- Balancing hectares growth and population growth (our computation) results in no change in food per capita at planetary scale

Our study:

- Neglect of diminishing returns and ecosystem stress (fertilizers, pesticides)
- More adults (higher caloric intake) in 2050 population
- Can one educate citizens globally? The case of tobacco

In conclusion the

“mismatch between what the world needed for everyone to enjoy a nutritious diet and what the world was actually producing”

is the substitution of a political problem with a technical one

Some examples:

Sensitivity auditing/Quantitative storytelling: Golden Rice's story

The Washington Post

Speaking of Science

107 Nobel laureates sign letter blasting Greenpeace over GMOs

By Joel Achenbach

https://www.washingtonpost.com/news/speaking-of-science/wp/2016/06/29/more-than-100-nobel-laureates-take-on-greenpeace-over-gmo-stance/

While Greenpeace and other organizations oppose genetically engineered food, more than 100 Nobel laureates are taking a stand on the side of GMOs. Here's a look at each side's arguments. (Jenny Starrs/The Washington Post)

"While Greenpeace and other organizations oppose genetically engineered food, more than 100 Nobel laureates are taking a stand on the side of GMOs. Here's a look at each side's arguments. (Jenny Starrs/The Washington Post)"

From the Nobel laureates' letter:

"Greenpeace has spearheaded opposition to Golden Rice, which has the potential to reduce or eliminate much of the death and disease caused by a vitamin A deficiency (VAD), which has the greatest impact on the poorest people in Africa and Southeast Asia.

[…] a total of one to two million preventable deaths occur annually as a result of VAD, […] VAD itself is the leading cause of childhood blindness globally affecting 250,000 – 500,000 children each year. Half die within 12 months of losing their eyesight"

From the Nobel laureates' letter:

"[…] Opposition based on emotion and dogma contradicted by data must be stopped.

How many poor people in the world must die before we consider this a "**crime against humanity**"?"

http://supportprecisionagriculture.org/nobel-laureate-gmo-letter_rjr.html

Opposing evidence on Golden Rice

Nutritionally: not enough beta carotene

Golden rice not authorized yet

More politically viable alternative successful

Dangerous colour

Low yield of the modified variety …

http://www.ecowatch.com/greenpeace-to-nobel-laureates-its-not-our-fault-golden-rice-has-failed-1896697050.html

.

With Mario Giampietro and Tiziano Gomiero

https://theconversation.com/forcing-consensus-is-bad-for-science-and-society-77079

.

Some examples:

Quantitative storytelling:

Cost Benefit Analyses

The myth of scientific quantification via risk or cost benefit analyses, including of the impact of new technologies, has been at the hearth of the critique of the ecological moment (e.g. Schumacher, 1973; Winner, 1986; Funtowicz and Ravetz, 1994)

E. F. Schumacher, 1973, Small Is Beautiful. Economics as if People Mattered, Penguin Perennial,

Winner, L., 1986. The Whale and the Reactor: a Search for Limits in an Age of High Technology. The University of Chicago Press, 1989 edition.

Funtowicz, S.O. and Ravetz, J.R. (1994). The worth of a songbird: Ecological economics as a post-normal science. Ecological Economics 10(3), 197-207.

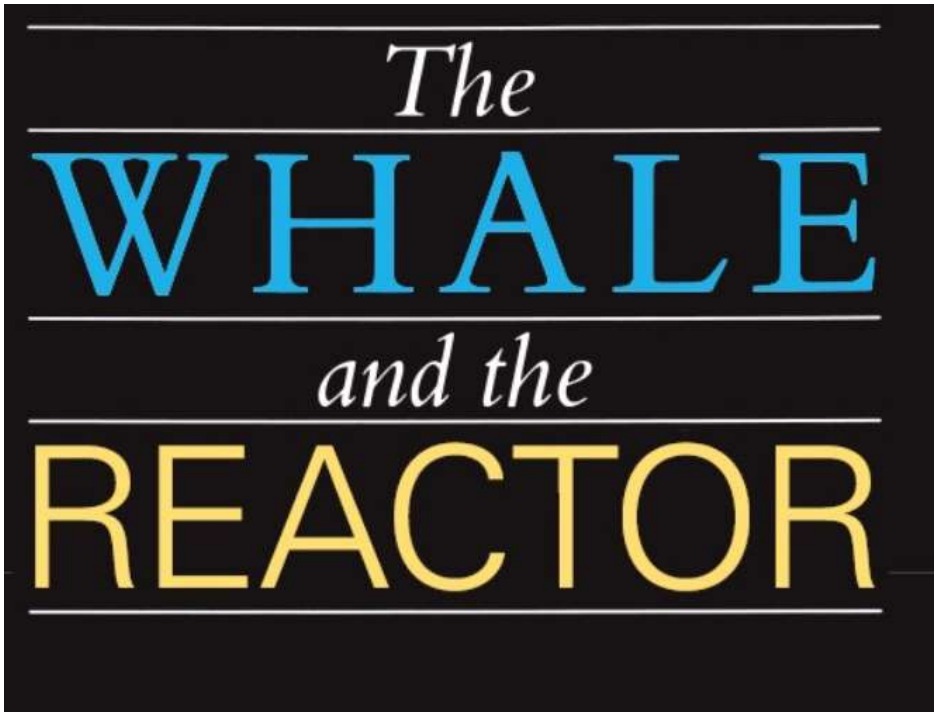
[…] quality is much more difficult to 'handle' than quantity, just as the exercise of judgment is a higher function than the ability to count and calculate.

Ernst Friedrich "Fritz" Schumacher

Quantitative differences can be more easily grasped and certainly more easily defined than qualitative differences: their concreteness is beguiling and gives them the appearance of scientific precision, even when this precision has been purchased by the suppression of vital differences of quality.

E. F. Schumacher, 1973, Small Is Beautiful. Economics as if People Mattered, Penguin Perennial,

Most analyses offered as input to policy are framed as cost benefit analysis or risk analyses



Langdon Winner

Winner, L., 1986. The Whale and the Reactor: a Search for Limits in an Age of High Technology. The University of Chicago Press, 1989 edition.

Read chapter 8

8

ON NOT HITTING
THE TAR-BABY

Langdon Winner

On not falling into the trap of CBA and risk analyses

Winner, L., 1986. The Whale and the Reactor: a Search for Limits in an Age of High Technology. The University of Chicago Press, 1989 edition.

Consume GMO because they are safe!

GMO as a food scare

The Economist, Vermont v science, The little state that could kneecap the biotech industry, May 10th 2014

Citizens' worries (Marris, 2001, excerpts)

- Who decided that they should be developed and how?
- 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?

Marris, C., Wynne, B., Simmons P., and Weldon, S. 2001. Final Report of the PABE research project funded by the Commission of European Communities, Contract number: FAIR CT98-3844 (DG12 - SSMI), December 2001.

US National Academy of Sciences report on genetically engineered crops:

"Products of new technologies should be regulated not only on the basis of their benefit-risk profiles, but also on their societal context and need"

Hunter, J., Duff, G., GM crops—lessons from medicine, Science, 353, 1187 (2016)

Training "Numbers for Policy", Barcelona
August 27th – September 1st

http://www.uib.no/en/svt/115575/numbers-policy-practical-problems-quantification

UNIVERSITY OF BERGEN

END

Twitter:
@andreasaltelli

Some examples:

Sensitivity auditing/Quantitative storytelling: The Ecological Footprint

Ecological Indicators 46 (2014) 610–621

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Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Footprints to nowhere

Mario Giampietro [a,c], Andrea Saltelli [b,*]

[a] Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain
[b] Institute for the Protection and Security of the Citizen (IPSC), The European Commission, Joint Research Centre, TP 361, 21027 Ispra, VA, Italy
[c] Catalan Institution for Research and Advanced Studies (ICREA), Passeig Lluís Companys, 23, 08010 Barcelona, Spain

Giampietro, M., and Saltelli, A., 2014, Footprints to nowhere, Ecological Indicators, 46, 610–621.

Goldfinger, S., Wackernagel, M., Galli, A., Lazarus, E., Lin, D., 2014, Footprint facts and fallacies: A response to Giampietro and Saltelli (2014) "Footprints to Nowhere", 46, 622–632.

Giampietro, M., and Saltelli, A., 2014, Footworking in Circles, Ecological Indicators, 46 (2014) 260–263.

Alessandro Galli , Mario Giampietro , Steve Goldfinger, Elias Lazarus, David Lin, Andrea Saltelli , Matthis Wackernagel , Felix Müller, 2016, Questioning the ecological footprint , Ecological Indicators, 69, 224–232.

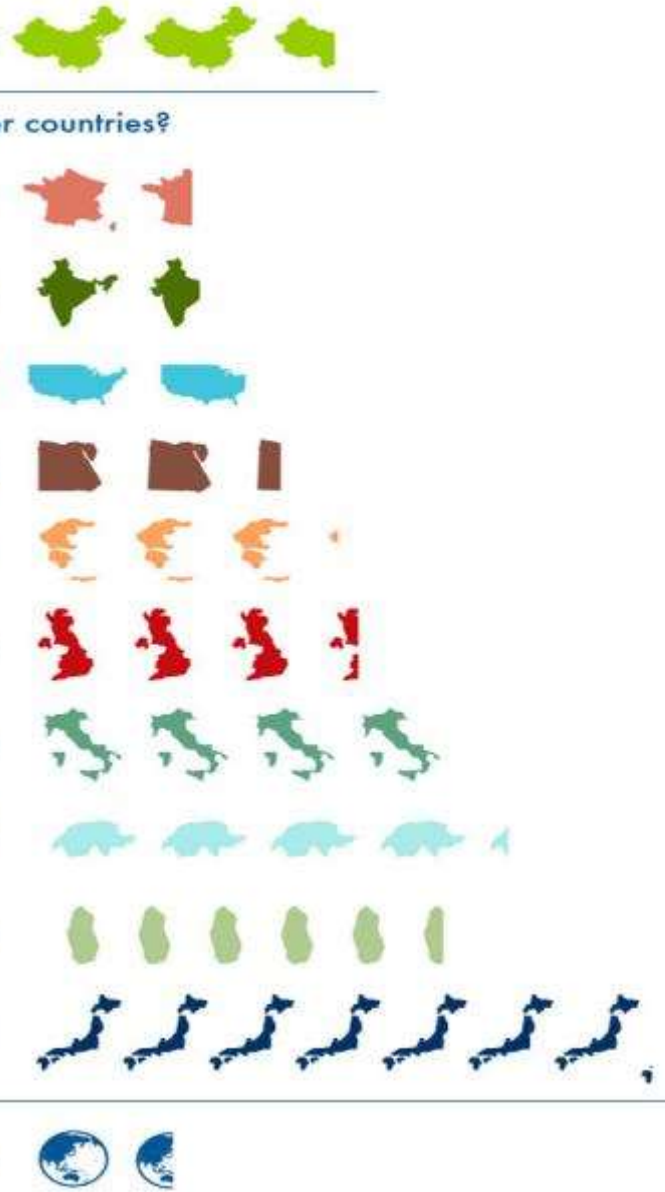
All the story . . .

How many Chinas does it take to support China?

CHINA	2.5

What about some other countries?

FRANCE	1.6
INDIA	1.8
U.S.A.	1.9
EGYPT	2.4
GREECE	3.1
U.K.	3.5
ITALY	4.0
SWITZER-LAND	4.2
QATAR	5.7
JAPAN	7.1
WORLD	1.5

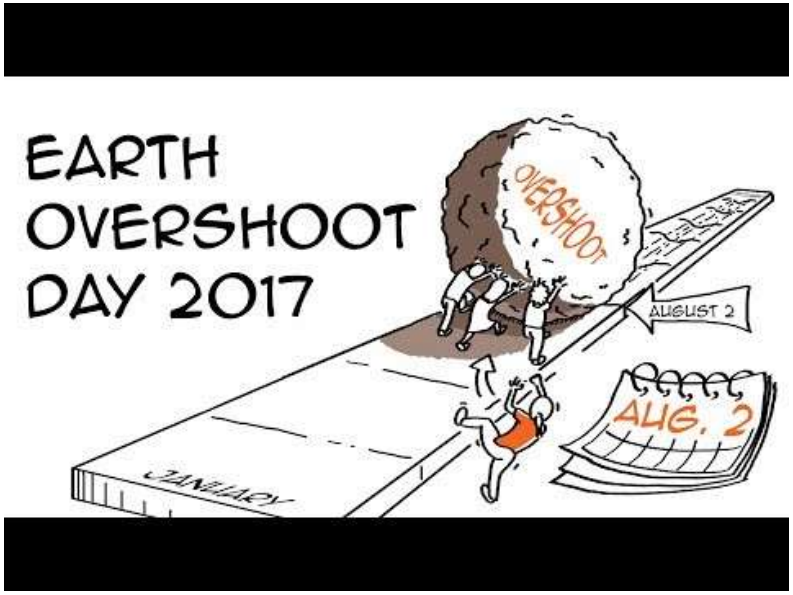


Based on two “accounts (biocapacity and footprint) representing the supply and demand of renewable biological resources, and the area of forest required to offset human carbon emissions (the carbon footprint)” the EF tells mankind how many planets are being used

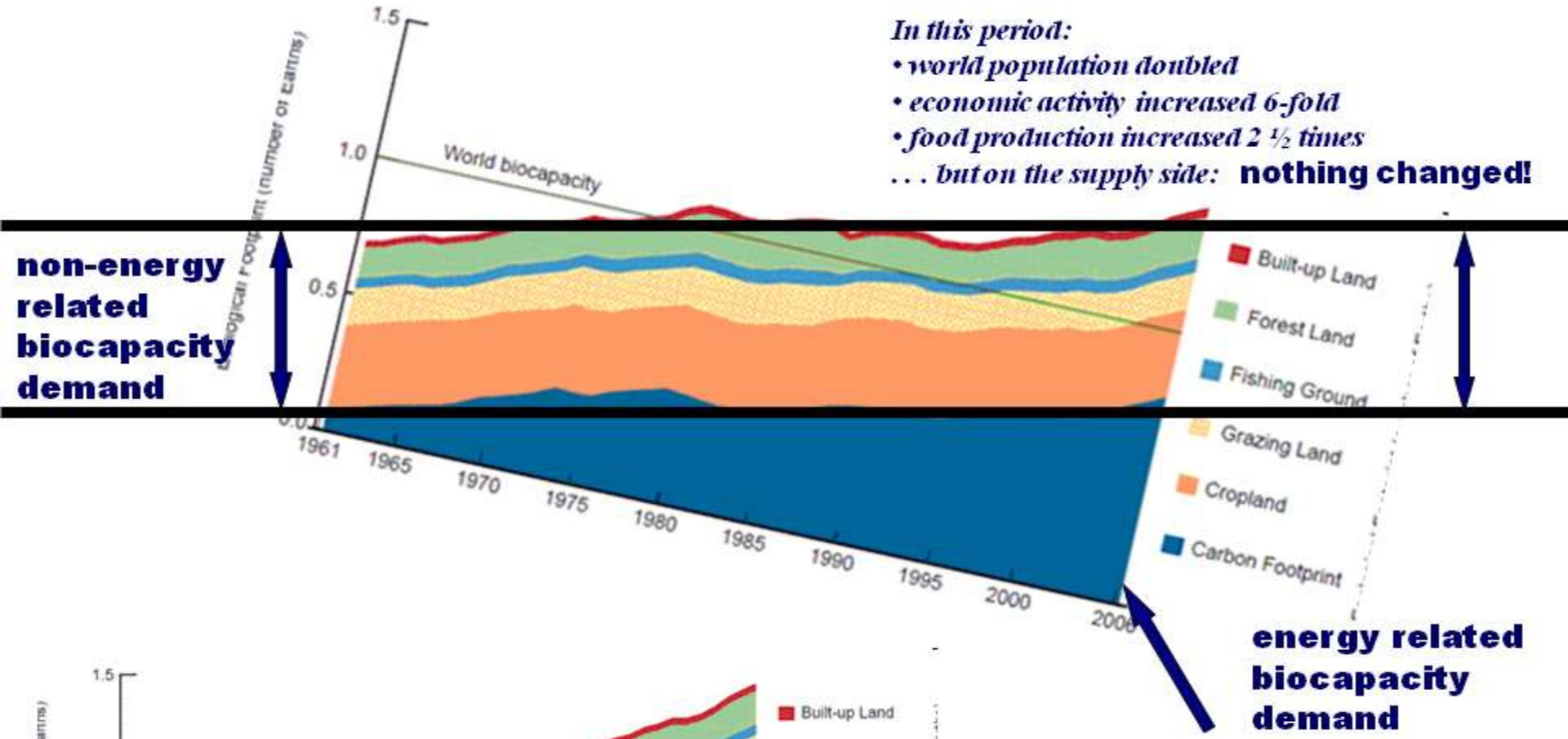

EARTH
OVER
SHOOT
DAY


EARTH
OVERSHOOT DAY
08. AUG. 2016
FAIRTRADE


Earth
Overshoot
Day 2015


EARTH
OVERSHOOT
DAY 2017
OVERSHOOT
AUGUST 2
AUG. 2
JANUARY

The change of world footprint in time (1961-2006)

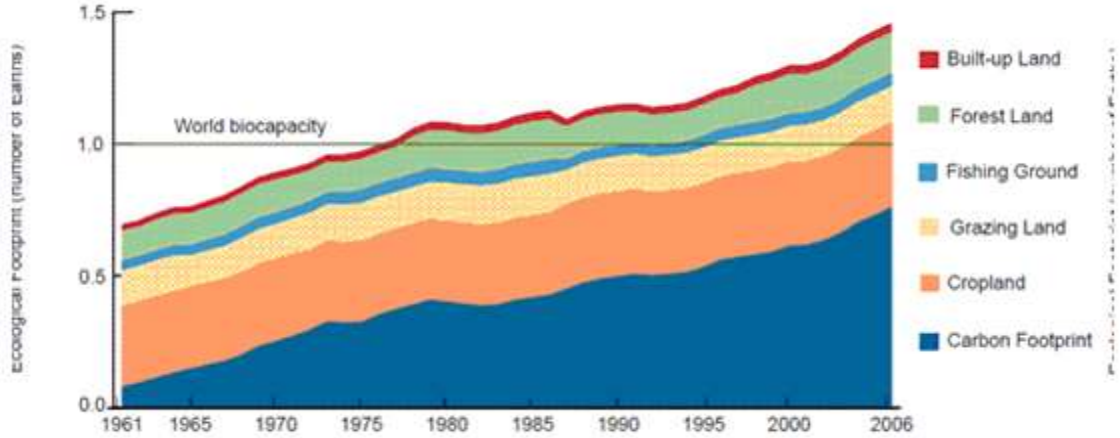


In this period:
- ***world population doubled***
- ***economic activity increased 6-fold***
- ***food production increased 2 ½ times***

. . . but on the supply side: **nothing changed!**

non-energy related biocapacity demand

energy related biocapacity demand



the only measured change in EF is generated by a very creative protocol converting energy use into hectares of planet . . .

The footprint is almost entirely driven by energy consumption, which corresponds to carbon emission which are in turn sequestrated by forests; [...] Carbon sequestration rate is hence what drives the results

But this number could be made negative as well as infinity depending on what number one picks ... it is totally volatile

Is the EF a rhetorical device?

- The implausible accuracy (Earth overshoot day = August 2!)
- Offsetting a flow with a stock (Kg of CO2 per year versus square meters of land)
- The anti-trade bias (CMEPSP, 2009, p. 71)
- The total dependence upon energy related pressures
- Paradoxical policy implications (e.g. in Agriculture)

Giampietro and Saltelli, Op. cit.

CMEPSP (2009). Commission on the Measurement of Economic Performance and Social Progress, URL: http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf last accessed June 2014.

Is the EF a rhetorical device?

- The EF is inconsistent with its stated purpose of measuring demand on ecosystems
- The EF depends mostly from a dimensionally flawed energy emissions assessment
- One cannot accept EF's flaws on the ground that the EF has normative virtues; EF's rhetoric muddles the sustainability debate

“EF measurements, as currently constructed and presented, are so misleading as to preclude their use in any serious science or policy context.[…], less than half the area of the United States planted with eucalypts could essentially give us an EF equal to one Earth—an approach that no ecologist would recommend.”

Blomqvist L, Brook BW, Ellis EC, Kareiva PM, Nordhaus T, et al. (2013a) Does the Shoe Fit? Real versus Imagined Ecological Footprints. PLoS Biol 11(11): e1001700. doi:10.1371/journal.pbio.1001700.

See also follow up:

Rees WE, Wackernagel M (2013) The Shoe Fits, but the Footprint is Larger than Earth. PLoS Biol 11(11): e1001701. doi:10.1371/journal.pbio.1001701

Blomqvist L, Brook BW, Ellis EC, Kareiva PM, Nordhaus T, et al. (2013b) The Ecological Footprint Remains a Misleading Metric of Global Sustainability. PLoS Biol 11(11): e1001702. doi:10.1371/journal.pbio.1001702.