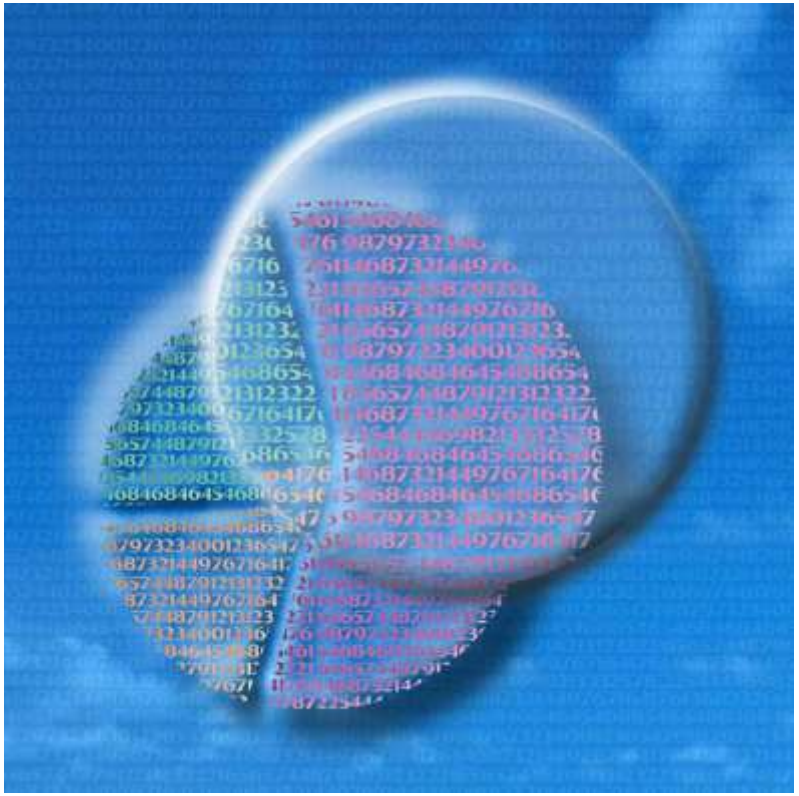


Methods: sensitivity auditing +

Andrea Saltelli
Centre for the Study of the Sciences and the Humanities, University of Bergen, and Open Evidence Research, Open University of Catalonia

Course MNF990 Theory of Science and Ethics, Bergen, September 13, 2018

Where to find this talk: www.andreasaltelli.eu

sensitivity analysis, sensitivity auditing, science for policy, impact assessment

= more material on my web site

Problematic quantifications

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

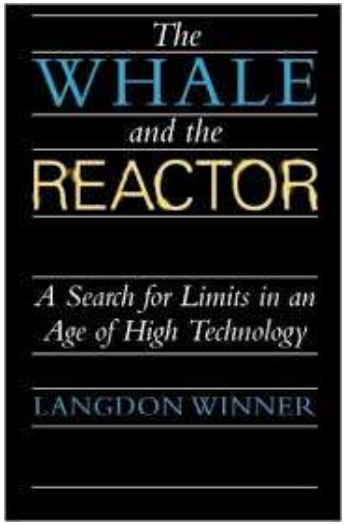
Quantitative differences can be more easily grasped and certainly more easily defined than qualitative differences: their concreteness is beguiling and gives them the appearance of scientific precision, even when this precision has been purchased by the suppression of vital differences of quality.

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

Frames

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

Langdon Winner



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ON NOT HITTING
THE TAR-BABY

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 and Ravetz ➔ poor quality in science for policy ➔ post normal science

J. Ravetz and S. Funtowicz

Post-Normal Science as a reaction to cost benefit and risk analysis applied to ecological problems:

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.

"How much is a songbird worth?"

Example: deconstruction of the economics of climate change

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.

About a paper (Nordhaus 1991) on the economics of the greenhouse effect "since the paper displays considerable sophistication in the handling of uncertainties in data."

"the paper by Nordhaus is liberally sprinkled with caveats..."

Nordhaus, W.D., 1991. To slow or not to slow: the economics of the greenhouse effect. Econ. J., 101: 920-937.

One such caveat is – in the words of William Nordhaus – the difficulty to move from the "terra infirma of climate change to the terra incognita of the social and economic impacts of climate change", but:

"[Although] in his rhetoric at least, the author shows a clear awareness of the presence of the various sorts of uncertainty, [...he] does not successfully manage the problems of uncertainty."

Table 1
Impact estimates for different sectors, for doubling of CO_2, U.S. (positive number indicates gain; negative number loss) (Nordhaus, 1991, Table 6, p. 932)

Sectors	Billions (1981 $)
Severely impacted sectors	
Farms	
Impact of greenhouse warming and CO_2 fertilisation	−10.6 to +9.7
Forestry, fisheries, other	Small + or −
Moderately impacted sectors	
Construction	+
Water transportation	?
Energy and utilities	
Energy (electric, gas, oil)	
Energy demand	−1.65
Non-electric space heating	1.16
Water and sanitary	−?
Real estate	
Land-rent component	
Estimate of damage from sea-level rise	
Loss of land	−1.55
Protection of sheltered areas	−0.90
Protection of open coasts	−2.84
Hotels, lodging, recreation	?
Total	
Central estimate	
Billions, 1981 level of national income	−6.23
Percentage of national income	−0.26

Sources for Table 6: Underlying data on impacts are summarised in EPA (1988). Translation into national-income accounts by author. Details are available on request.

"The hyper-precision in the expression of the key number -0.26% […] shows that this is one of those 'magic numbers' designed to produce confidence in the existence of a hard core of objective fact deep inside the mass of intuitive fuzz."

For Nordhaus - based on a 'hunch' this -0.26% could become -2% …

Table 1
Impact estimates for different sectors, for doubling of CO_2, U.S. (positive number indicates gain; negative number loss) (Nordhaus, 1991, Table 6, p. 932)

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A more recent paper:

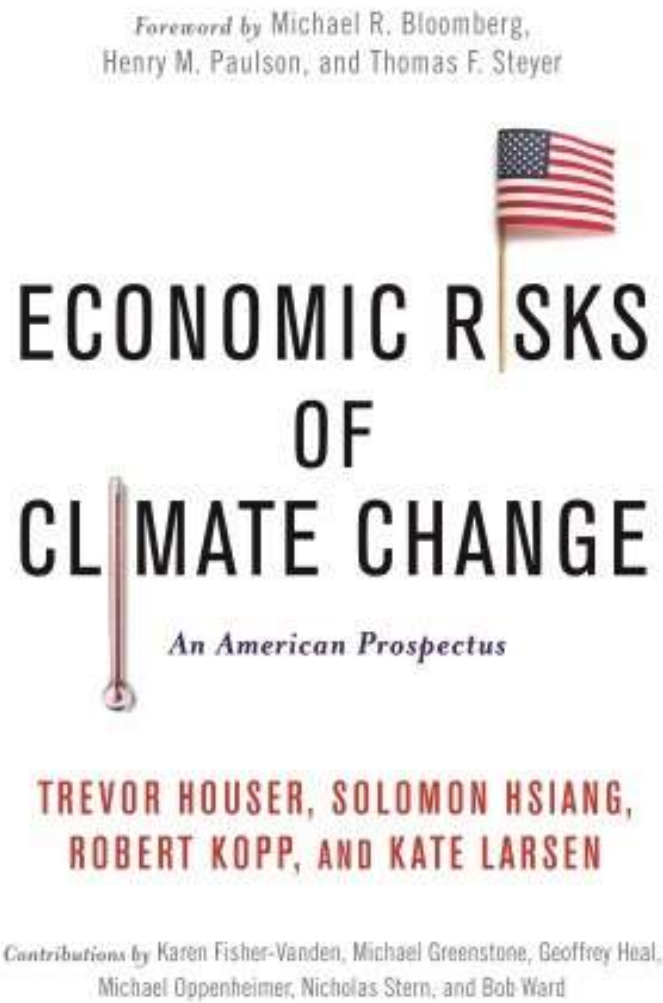
ANDREA SALTELLI
PHILIP B. STARK
WILLIAM BECKER
PAWEL STANO

Climate Models as Economic Guides

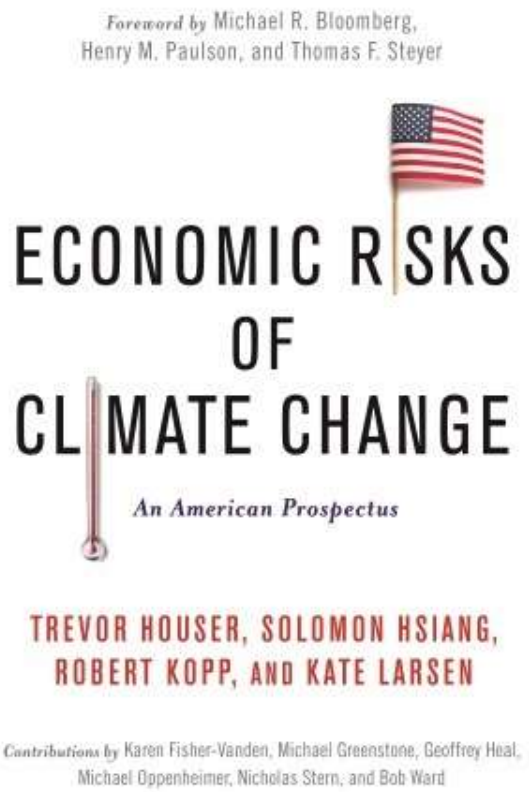
Scientific Challenge or Quixotic Quest?

The uncertainties associated with mathematical models that assess the costs and benefits of climate change policy options are unknowable. Such models can be valuable guides to scientific inquiry, but they should not be used to guide climate policy decisions.

An audacious study:

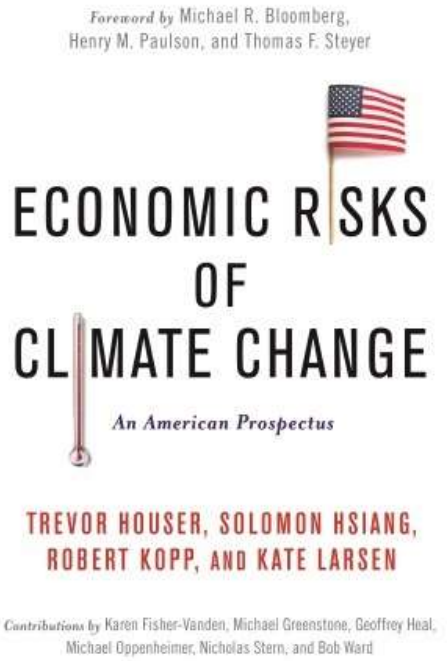


"[…] the report forecasts—at the level of individual counties in the U.S.—energy costs and demand, labor supply, mortality, violent crime rates, and real estate property prices up to the year 2100 […]"

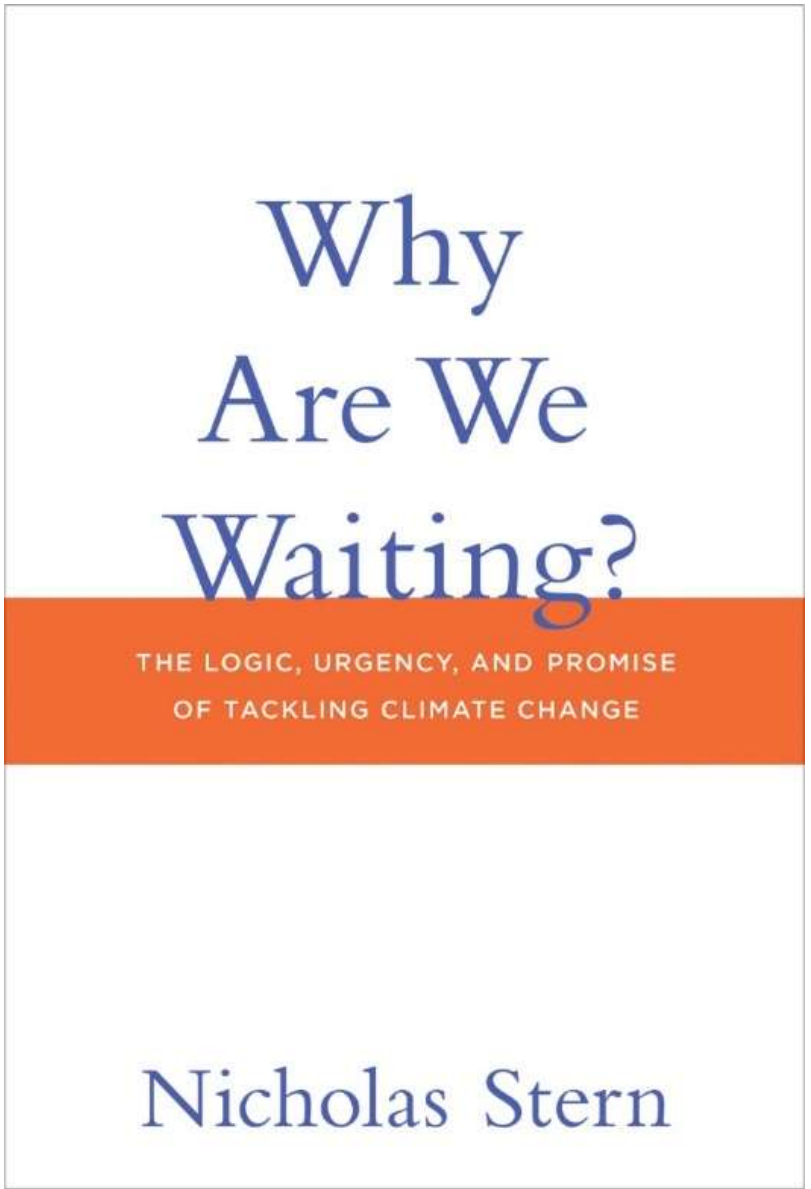


"The report presents the amount of computer power and data generated as evidence of the scientific legitimacy of the enterprise.

The authors note, however, that out of an abundance of caution they did not model deterioration in cognitive performance as temperatures rise"



Latest (2015) book of Nicholas Stern Advocates for better integrated assessment models (IAM)

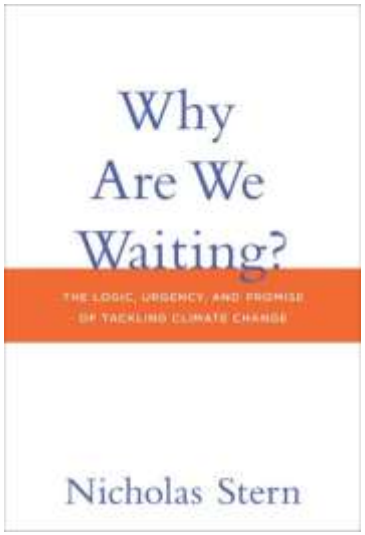


THE LOGIC, URGENCY, AND PROMISE OF TACKLING CLIMATE CHANGE

After a list of criticism moved to the realism of Integrated Assessment Models:

"[…] the point is that estimates based on these models are very sensitive to assumptions and are likely to lead to gross underestimation" p.139

Things to be incorporated in ‘formal modelling’



“Damage to social, organizational or environmental capital […]

Damage to stock of capitals and land […]

Damage to overall factor productivity […]

Damage to learning and endogenous growth”, p. 145

‘formal modelling’ as to produce ‘numbers’?

N. Stern suggests using different mathematical models, including dynamic stochastic general equilibrium models (DSGE)

Philip Mirowski: a critique of DSGE as used in economics; inquiries by the US senate and the Queen of the England about their failure to predict the crisis

Philip Mirowski

Everybody in the profession knows that DSGE work under the economists' standard 'caeteris paribus' hypothesis (=all the rest being equal)

Start here But

Caeteris are never paribus

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.

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.

The rules of sensitivity auditing ca be used as columns for NUSAP pedigree matrix

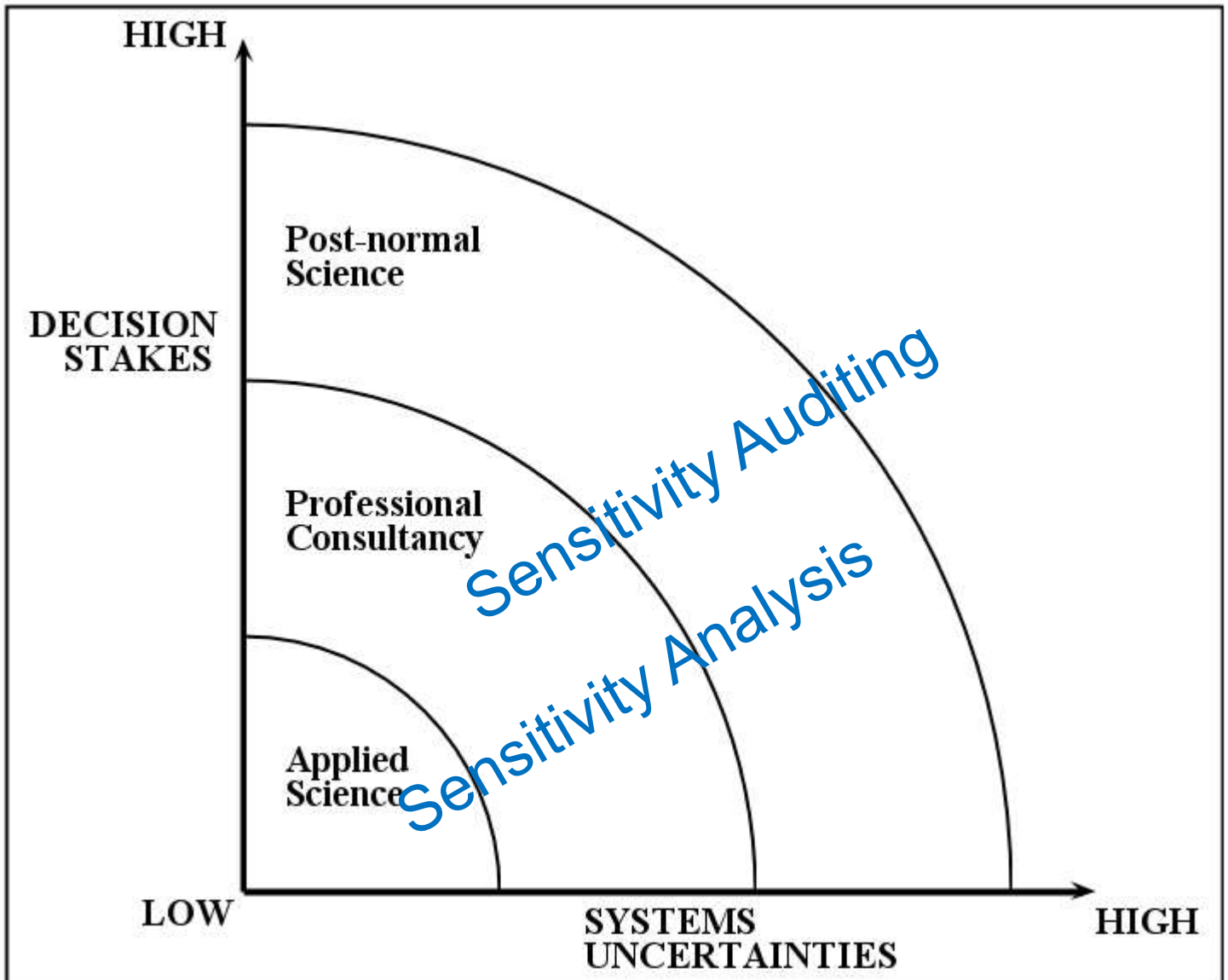
Universiteit Utrecht

Example Pedigree matrix parameter strength

Code	Proxy	Empirical	Theoretical basis	Method	Validation
4	Exact measure	Large sample direct mmts	Well established theory	Best available practice	Compared with indep. mmts of same variable
3	Good fit or measure	Small sample direct mmts	Accepted theory partial in nature	Reliable method commonly accepted	Compared with indep. mmts of closely related variable
2	Well correlated	Modeled/derived data	Partial theory limited consensus on reliability	Acceptable method limited consensus on reliability	Compared with mmts not independent
1	Weak correlation	Educated guesses / rule of thumb est	Preliminary theory	Preliminary methods unknown reliability	Weak / indirect validation
0	Not clearly related	Crude speculation	Crude speculation	No discernible rigour	No validation

Jeroen van der Sluijs

http://www.nusap.net/


HIGH
DECISION STAKES
Post-normal Science
Professional Consultancy
Applied Science
Sensitivity Auditing
Sensitivity Analysis
LOW
SYSTEMS UNCERTAINTIES
HIGH

Some examples:

Sensitivity auditing: the OECD PISA study

Do PISA data justify PISA-based education policy?

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

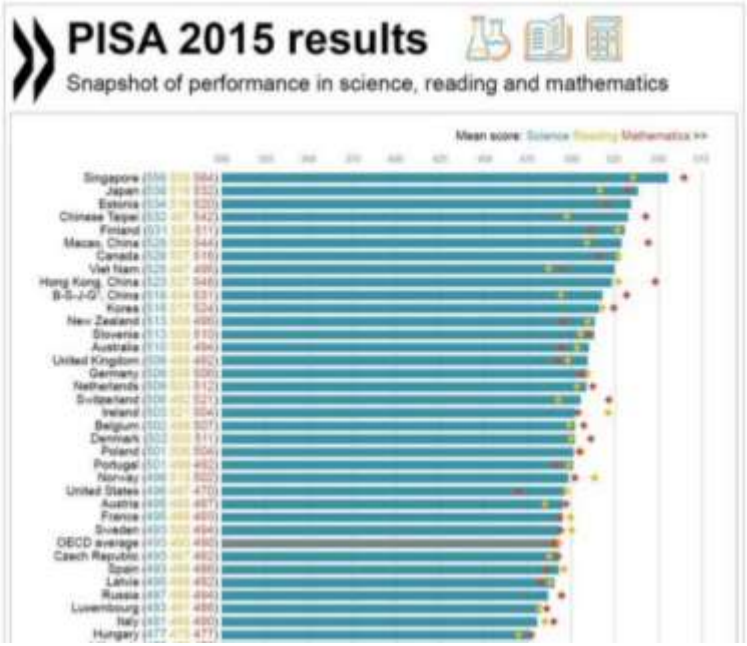
Academic rigour, journalistic flair

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

theguardian

OECD and Pisa tests are damaging education worldwide - academics

In this letter to Dr Andreas Schleicher, director of the OECD's Programme for International Student Assessment, academics from around the world express deep concern about the impact of Pisa tests and call for a halt to the next round of testing

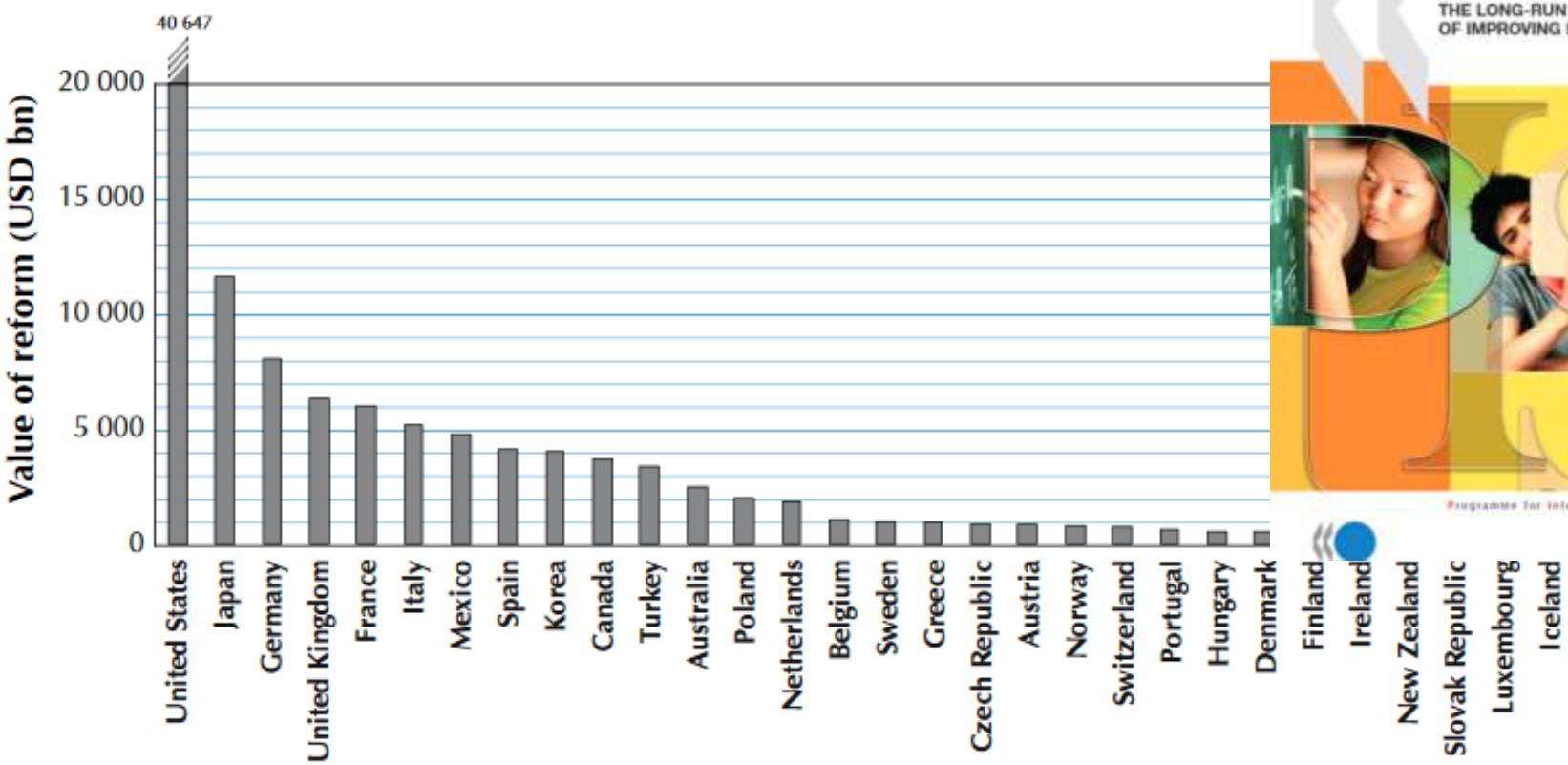
School children in Sichuan province in China. Academics say the OECD should develop alternatives to league tables and find more meaningful ways of reporting assessment, taking account of different cultures. Photograph: James Zeng Huang/Corbis Sygma

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 (which is what for example Germany and Poland achieved 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.

Our study identifies both technical and normative issues:

1) Non response bias (what 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

Our study identifies both technical and normative issues:

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: Golden Rice's story

Skip

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 Noble 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 Noble 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

.

“What climate, vaccines and GMOs have in common”

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

.

Start here

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).

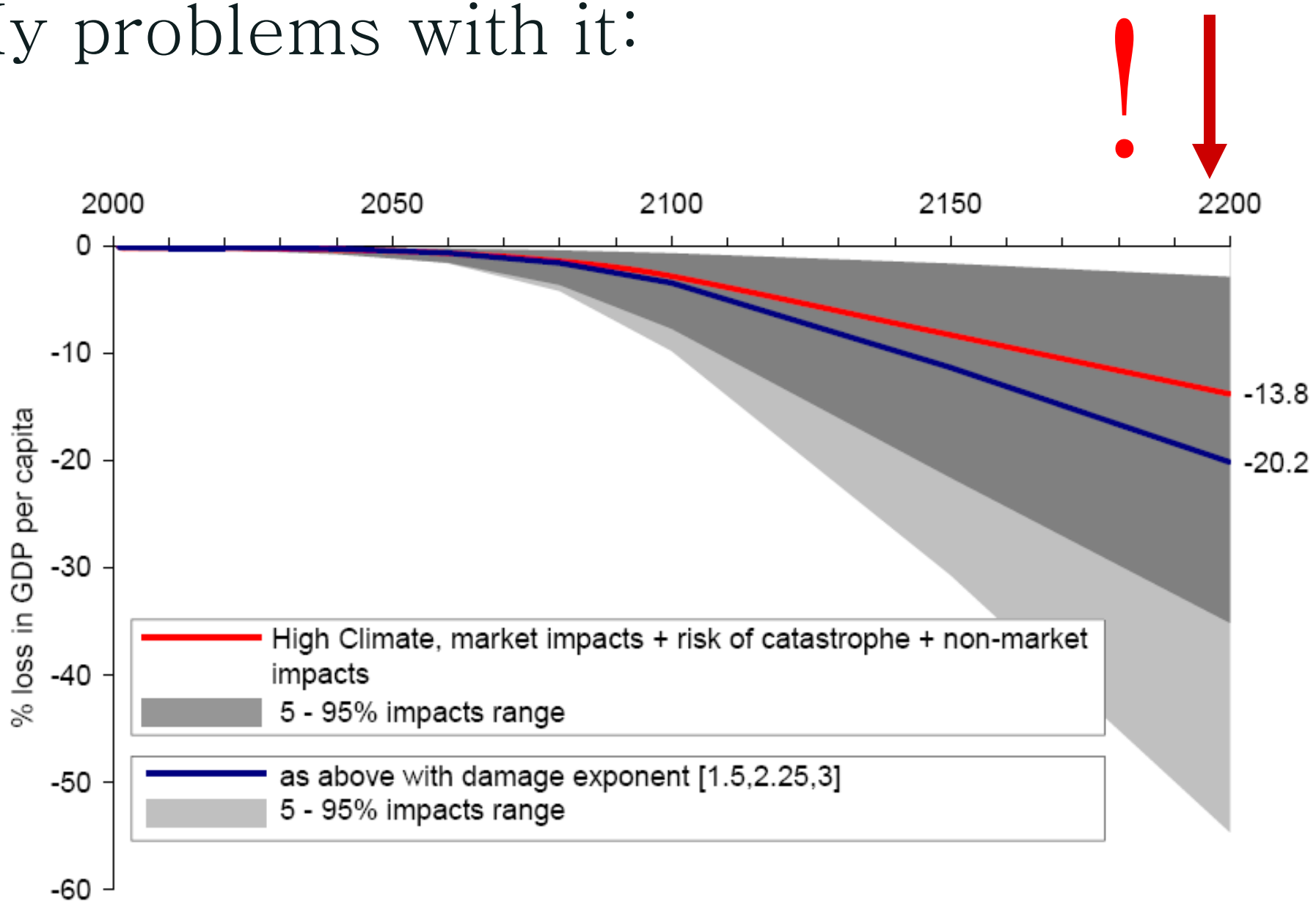
The Stern – Nordhaus exchange on *SCIENCE*

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 infers: My analysis shows robustness'

My problems with it:

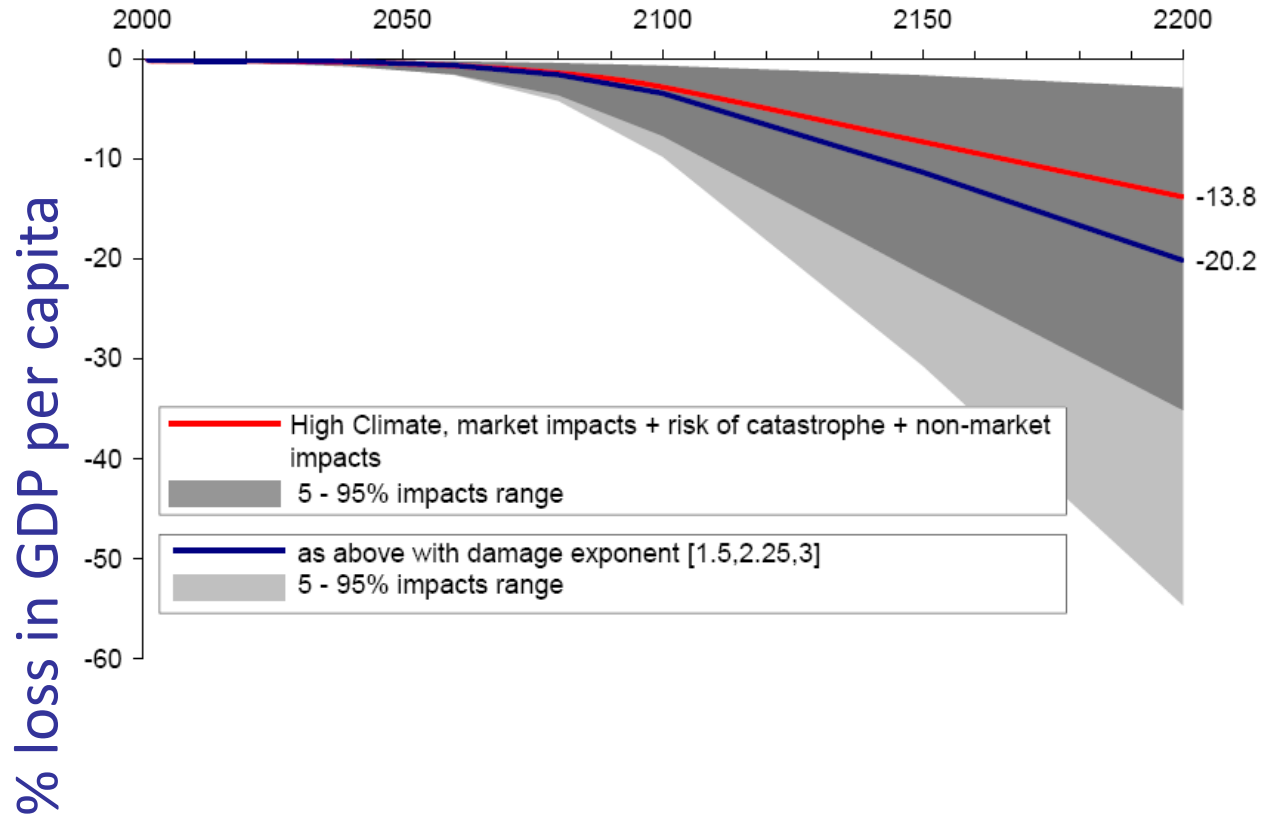


… but foremost Stern says:

changing assumptions → important effect

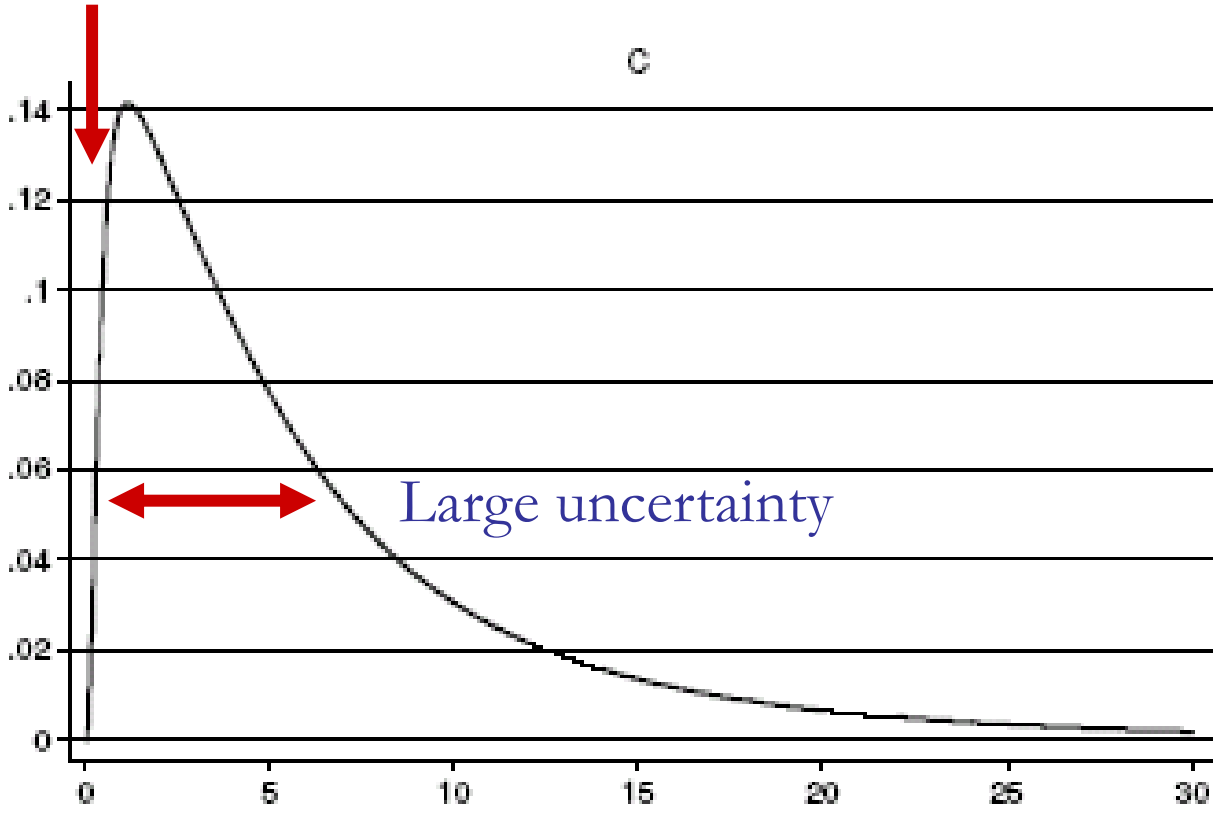
when instead he should admit that:

changing assumptions → all changes a lot

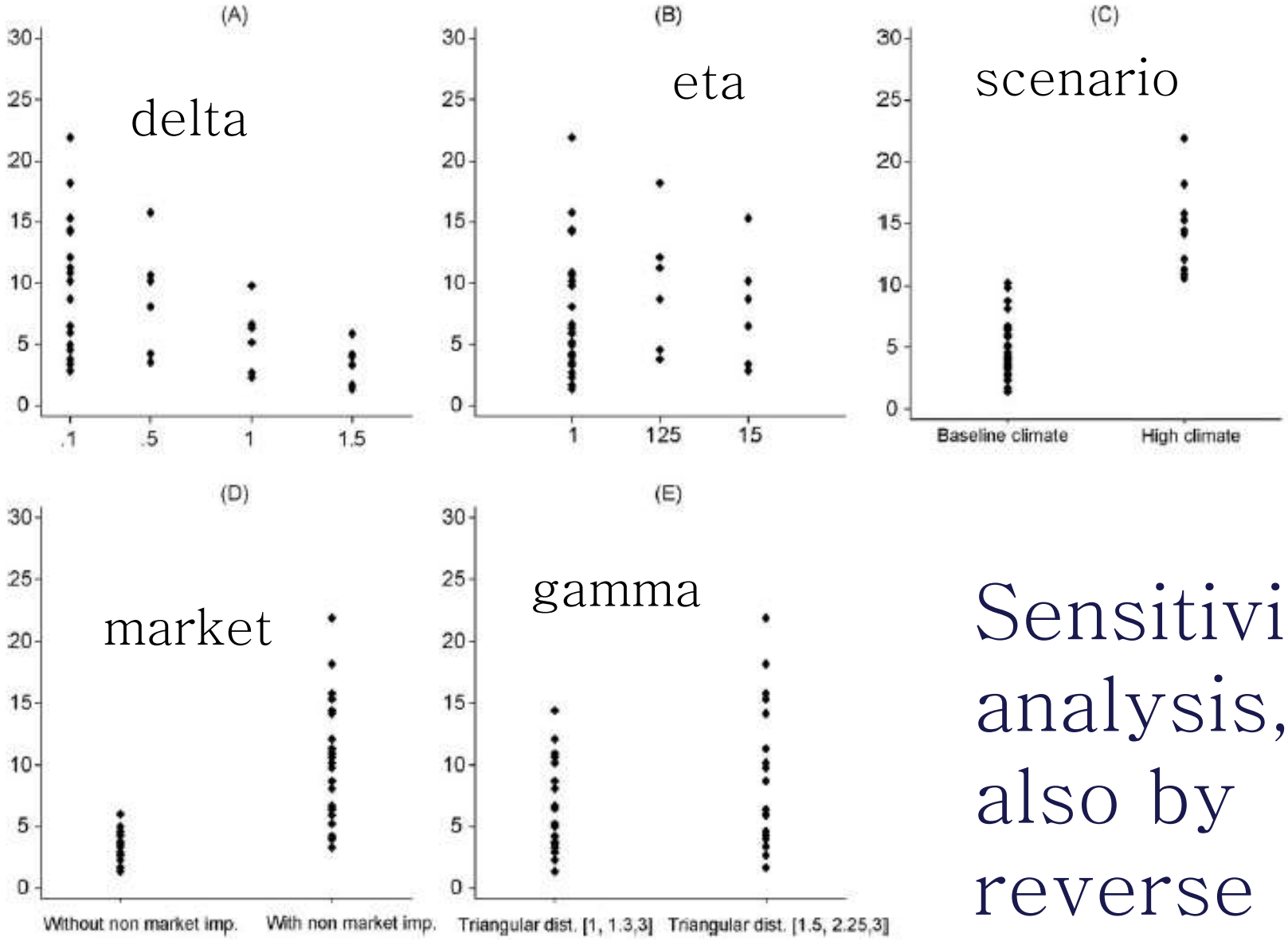


How was it done? A reverse engineering of the analysis

Missing points

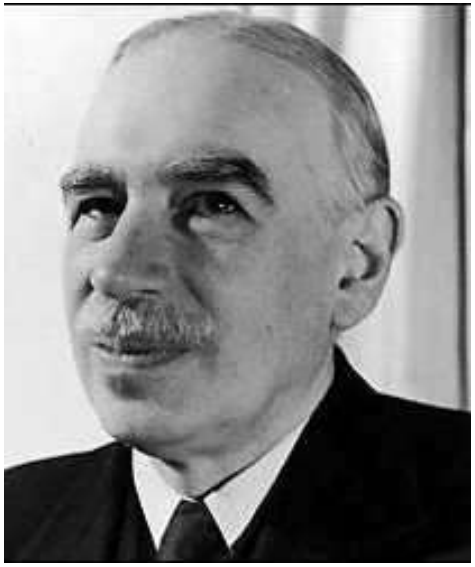


% loss in GDP per capita



Sensitivity analysis, also by reverse engineering

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



… precisely wrong

From: Saltelli, A., D'Hombres, 2010, Sensitivity analysis didn't help. A practitioner's critique of the Stern review, *GLOBAL ENVIRONMENTAL CHANGE*, 20, 298-302.

Stop here

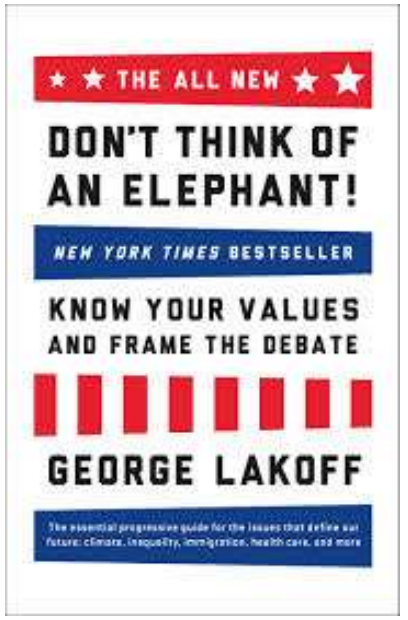
Quantitative story-telling

“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).

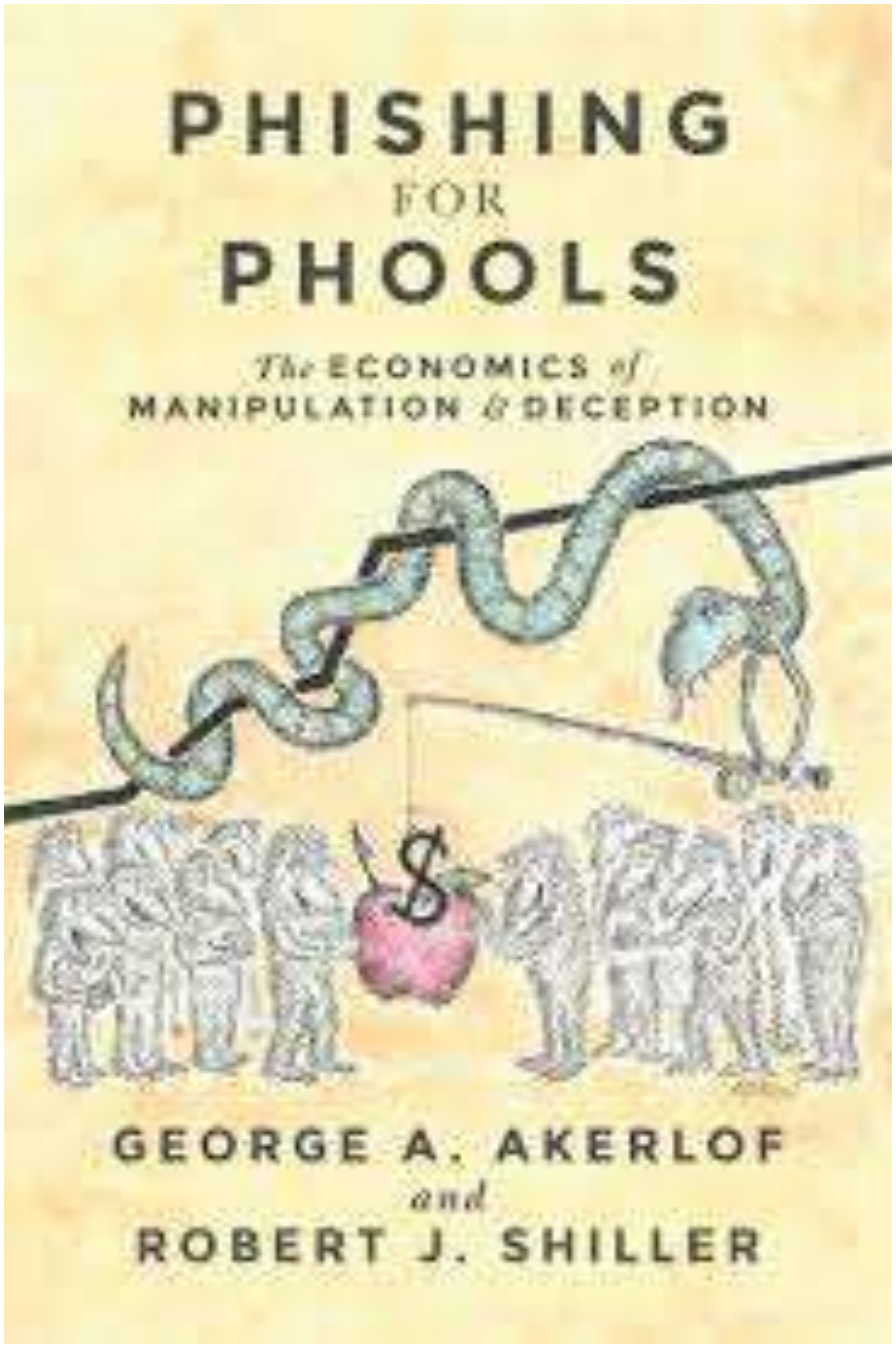
George Lakoff



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 is possible only through processes of exclusion. Storytelling is possible only because of the mass of detail that we leave out. Knowledge is possible only through the systematic ‘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 to deal with "uncomfortable knowledge".

1. Denial: "There isn't a problem"

2. Dismissal: "It's a minor problem"

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 to deal with "uncomfortable knowledge".

3. Diversion: "Yes I am working on it" (In fact I am working on something that is only apparently related to 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.

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

4. Displacement: "Yes and the model we have developed tells us that real 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.

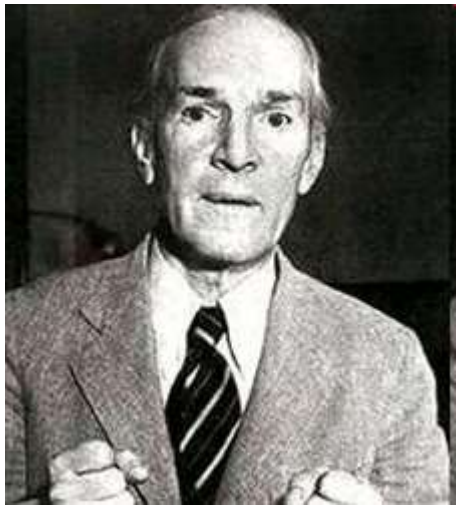
“Uncomfortable knowledge” can be used as a gauge of an institution’s health.

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 auditing/Quantitative storytelling: The Ecological Footprint

Ecological Indicators 46 (2014) 610–621

Contents lists available at ScienceDirect

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	

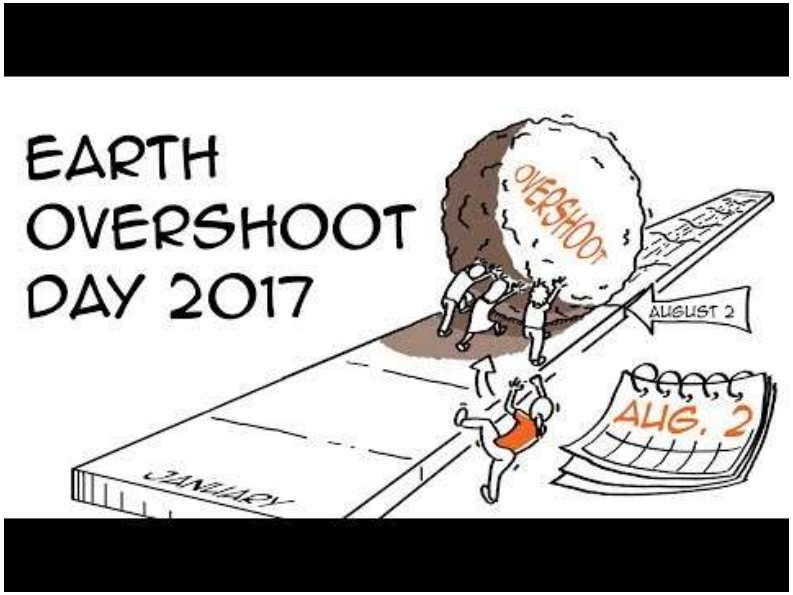
WORLD	1.5	

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

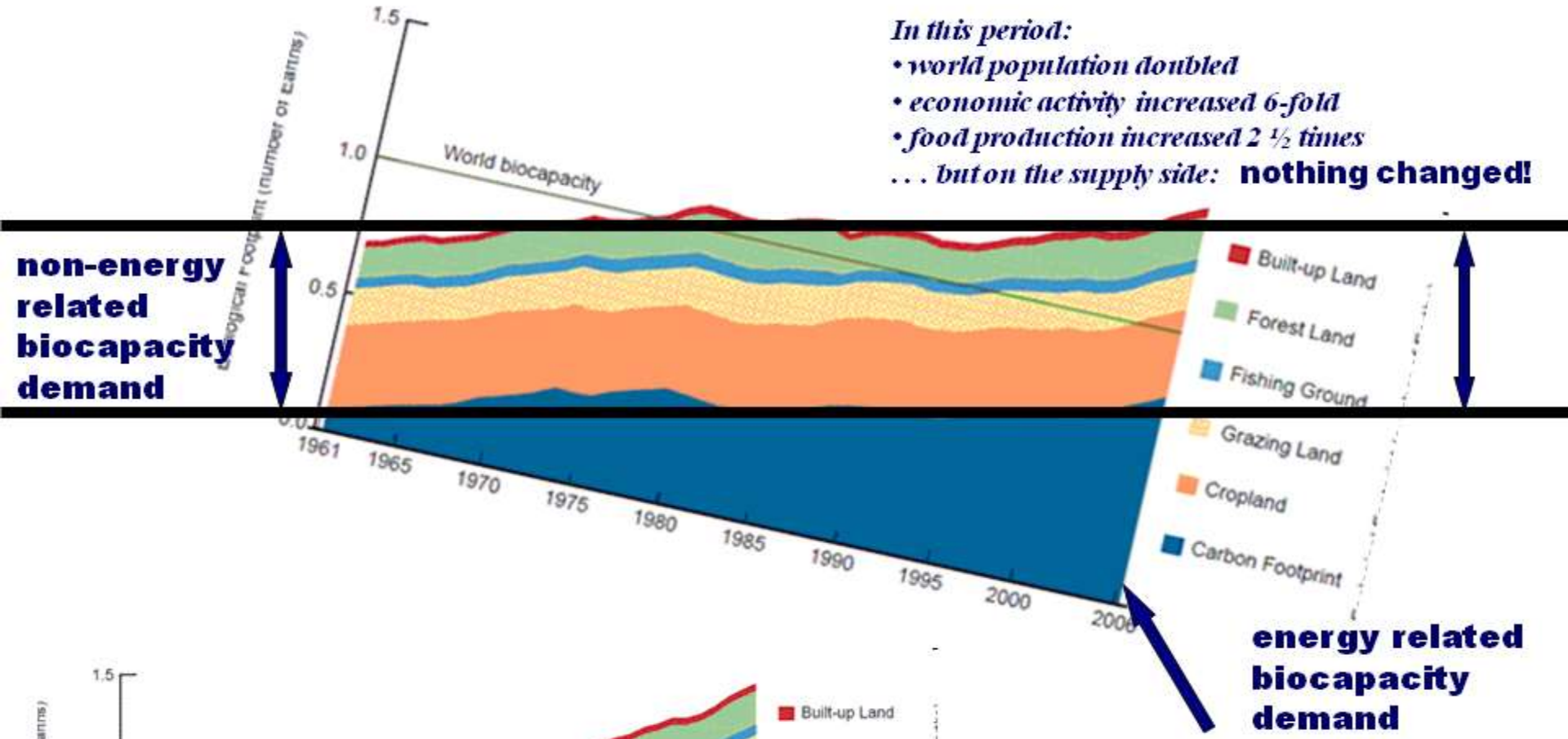

EARTH
OVER
SHOOT
DAY


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)

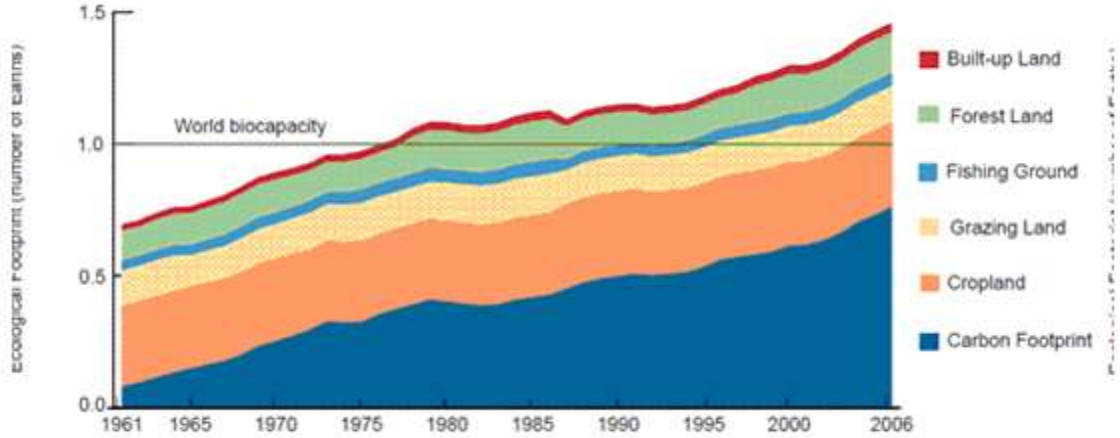


In this period:
- ***world population doubled***
- ***economic activity increased 6-fold***
- ***food production increased 2 ½ times***

. . . 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.

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.

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., Science, GM crops—lessons from medicine, 353, 1187 (2016)

As noted in the field of economics, mathematization is cyclical

Reinert, Erik S., 2000, Full circle: economics from scholasticism through innovation and back into mathematical scholasticism Reflections on a 1769 Price essay: “Why is it that economics so far has gained so few advantages from physics and mathematics?”, Journal of Economic Studies 27,4/5, 364 -376.

‘Decisionism’ was high after WW2 (RAND corporation, linear programming, decision analysis), then the ecological critique of the 70’s; then Milton Friedman and the neoliberals brought back faith e.g. in econometrics/counterfactual analysis, today in a new crisis…

The End

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