

Quantitative tools for responsible quantification

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= more material on my web site



= discussion time



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

Recipes for diligent quantification

A new grammar for modelling



grammar of modelling

Andrea Saltelli

(Submitted on 18 Dec 2017)





Sensitivity analysis

<u>Saltelli, A., Annoni, P., 2010, How to avoid a perfunctory sensitivity</u> <u>analysis, Environmental Modeling and Software, 25, 1508–1517.</u>

Sensitivity auditing

Saltelli, A., Funtowicz, S., 2014, When all models are wrong: More stringent quality criteria are needed for models used at the sciencepolicy interface, Issues in Science and Technology, Winter 2014, 79– 85.

Quantitative storytelling

Andrea Saltelli, Mario Giampietro, 2017, What is wrong with evidence based policy, and how can it be improved? Futures, DOI: http://dx.doi.org/doi:10.1016/j.futures.2016.11.012.

A new grammar

Andrea Saltelli, Does Modelling need a reformation? Ideas for a new grammar of modelling



Sensitivity analysis book available on LibGen







An engineer's vision of UA, SA



One can sample more than just factors One can sample modelling assumptions Example: The output is a composite indicator

Assumption	Alternatives
Number of indicators	 all six indicators included or
	one-at-time excluded (6 options)
Weighting method	 original set of weights,
	 factor analysis,
	 equal weighting,
	 data envelopment analysis
Aggregation rule	 additive,
	 multiplicative,
	 Borda multi-criterion



How is sensitivity analysis done?

 y_1 x_{11} x_{12} ... x_{1k} x_{21} x_{22} ... x_{2k} y_2 y_N x_{N1} x_{N2} ... x_{Nk}

Input matrix

Output vector:



Input matrix:

- Each column is a sample from the distribution of a factor
- Each row is a sample trial to generate a value of *y*

Examples of distributions of input factors





Output vector:

- Just one output of interest; but *y* could also be a vector (function of time) or a map, etc. …
- Y can be plotted against any of the \mathbf{x}_i

Y plotted against two different factors x_i and x_j



The values of the output on the ordinate are the same

Can I do a sensitivity analysis just looking at the plots?



Output variable 🗲





Input variable x_j



Which factor is more important?

Why?





~1,000 blue points Divide them in 20 bins of ~ 50 points

Compute the bin's average (pink dots)







Take the variance of the pink points and you have a sensitivity measure

 $V_{X_i}\left(E_{\mathbf{X}_{\sim i}}\left(Y|X_i\right)\right)$





Which factor has the highest $V_{X_i}\left(E_{\mathbf{X}_{\sim i}}\left(Y|X_i\right)\right)$?

$S_i \equiv \frac{V(E(Y|X_i))}{V_Y}$

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

	Better Regulation	vencel (remarch searce) (Euditeu (eu)
European Commission European Commanies > Bether Regulato Home	n > Politima Better Regulation Guidelines	🕼 Share 🛛 🖬 🕅 🕾 🛏
REFIT Stakeholar consultations Roadmaps / Inception Impact Assessment Evaluation Regulatory Scrutiny Board Guidelines Better Regulation Guidelines Better Regulation Guidelines	These guidelines explain what Better Regulation is and how it should be applied in the day to day practices when preparing new initiatives and proposals or managing susting policies and legislation. They cover the whole policy cycle, from policy preparation and adoption to implementation and application, to evaluation and revision of EU law. For each of these phases there are a number of Better Regulation principles, objectives, tools and procedures to make size that the EU has the best regulation possible. These relates to planning, impact assessment, stakeholder consultation, implementation and evaluation. The <u>Better Regulation Guidelines</u> are structured into chapters which cover each of the instruments of the law-maintog process. The corresponding toolbox gives more detailed and technical information. Better Regulation Guidelines are based on the outcomes of public consultation exercises carried out in 2013 and 2014.	Search Stay connected Stay connected Traceous Thatle Active Instead Latest documents 1005/2015 - Better Regulation Packago Help us improve
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Source: IA Toolbox, p. 391



EUROPEAN COMMISSION

Better Regulation "Toolbox"

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Will any sensitivity analysis do the job? Can I lie with sensitivity analysis as I can lie with statistics?



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

Why not just changing one factor at a time (OAT)?

Because it is a bad idea!

OAT in 2 dimensions



Area circle / area square =?

~ 3/4

OAT in 3 dimensions



Volume sphere / volume cube =?

~ 1/2

OAT in 10 dimensions Volume hypersphere / volume ten dimensional hypercube =? ~ 0.0025





Bottom-line: once a sensitivity analysis is done via OAT there is no guarantee that either uncertainty analysis (UA) or sensitivity analysis (SA) is any good:

→ UA will be non conservative

→ SA may miss important factors



2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014



Ferretti, F., Saltelli A., Tarantola, S., 2016, Trends in Sensitivity Analysis practice in the last decade, Science of the Total Environment, http://dx.doi.org/10.1016/j.scitotenv.2016.02.133

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 one when one wants to prove that a question cannot be answered given the model

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/model which can be treated meaningfully.

[Often the love for the 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/smartregulation/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, $[\cdots]$ 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.

 $\left[\cdots \right]$

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



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 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 that is only apparently related to the problem)
- 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 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



William Nordhaus, University of Yale



Nicholas Stern, London School of Economics

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



% 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 ...





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. Some examples: Sensitivity auditing: the OECD PISA study

Do PISA data justify PISA-based education policy?

PISA-based education policy



International Journal of Comparative Education and Development Vol. 19 No. 1, 2017 pp. 1-17 © Emerald Publishing Limited 2396-7404 DOI 10.1108/IJCED-12-2016-0023





Q. Search analysis: measurch, academics....

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



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

http://www.theguardian.com/e ducation/2014/may/06/oecdpisa-tests-damagingeducation-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



① 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
 - $\bullet \dots \rightarrow \text{Stop the test!}$
- 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/thehighcostofloweduca tionalperformance.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: 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 Piano¹

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Home / Pathways Leading to a More Sustainable and Healthy Global Food System

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Pathways Leading to a More Sustainable and Healthy Global Food System

Volume 7 | Issue 5 | Page 10-12 | September 2016 By Krishna Bahadur KC, Evan D.G. Fraser, Samantha Pascoal, Goretty Dias, Trudi Zundel



"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-leadingsustainable-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.

 $[\cdots]$ 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

107 Nobel laureates sign letter blasting Greenpeace over GMOs

https://www.washingtonpost.com/news/ speaking-ofscience/wp/2016/06/29/more-than-100-nobel-laureates-take-ongreenpeace-over-gmo-stance/



tille Greenpeace and littler organizations oppose genetically engineered food, more than 150 Nobel lawrates are taking a stand on the side (GMOs. Here's a look ut each side's arguments. (Jenny Stars/The Washington Past)

"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

Some examples: Sensitivity auditing/Quantitative storytelling: The Ecological Footprint



Contents lists available at ScienceDirect

Ecological Indicators

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

Footprints to nowhere

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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.





How many Chinas does it take to support China?



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











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



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.

[…] 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.



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 biotecl industry, May 10th 2014

Citizens' worries (Marris, 2001, excerpts)



- 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)



END

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