



Why science's crisis should not become a political battling ground

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ABSTRACT

A science war is in full swing which has taken science's reproducibility crisis as a battleground. While conservatives and corporate interests use the crisis to weaken regulations, their opponent deny the existence of a science's crisis altogether.

Thus, for the conservative National Association of Scholars NAS the crisis is real and due to the progressive assault on higher education with ideologies such as “neo-Marxism, radical feminism, historicism, post-colonialism, deconstructionism, post-modernism, liberation theology”. In the opposite field, some commentators claim that there is no crisis in science and that saying the opposite is irresponsible.

These positions are to be seen in the context of the ongoing battle against regulation, of which the new rules proposed at the US Environmental Protection Agency (EPA) are but the last chapter. In this optic, Naomi Oreskes writes on Nature that what constitutes the crisis is the conservatives' attack on science.

This evident right-left divide in the reading of the crisis is unhelpful and dangerous to the survival of science itself. An alternative reading ignored by the contenders would suggest that structural contradictions have emerged in modern science, and that addressing these should be the focus of our attention.

1. The context

For a long time, the fight between regulators and regulated has taken the form of the uncertainty game, whereby regulators and regulated would contend on the extent of uncertainty, e.g. with corporate powers trying to inflate the uncertainty in order to deter regulation (Michaels, 2008). This war has now extended to involve science's reproducibility crisis, whereby entire fields of research, from pre-clinical and clinical medicine to psychology, from organic chemistry to applied economics, have seen their findings resisting attempts at replication by independent studies (Benessia et al., 2016; Harris, 2017; Ioannidis et al., 2005; Ioannidis et al., 2014; Ioannidis et al., 2017).

This new development is evident in the rule recently proposed by EPA (EPA & OA, 2018):

“The rule will ensure that the regulatory science underlying Agency actions is fully transparent, and that underlying scientific information is publicly available in a manner sufficient for independent validation.” [...]

“The rule is in line with the scientific community's moves toward increased data sharing to address the “replication crisis”—a growing recognition that a significant proportion of published research may not be reproducible”,

Thus, the old conservative agenda of using transparency as a weapon against regulation (Michaels, 2008) is now combined with

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the opportunity offered by the reproducibility crisis.

A perverse result of this attack is that the existence of the crisis is denied by those who intend to defend science.

Thus, for Kathleen Hall Jamieson and Daniele Fanelli writing on PNAS (Jamieson, 2018; Fanelli, 2018) we do not have a crisis, while we do for the National Association of Scholars (NAS), a conservative think tank. For Naomi Oreskes what makes the crisis in science is the attack itself (Oreskes, 2018), i.e.: “*The crisis is the attempt to discredit scientific findings that threaten powerful corporate interests*”.

Jamieson (2018) moves from the premise that science is the most reliable form of knowledge generation humans have devised, and that it is self-correcting. Noting that measures are taken by science to fight science’s mistakes and misbehaviours - and reviewing critically the ‘science is broken’ narrative, this author concludes that mentions of ‘science’s crisis’ or ‘science is broken’ are misplaced or histrionic, unwarranted generalizations. Jamieson then instructs journalist on how they should report – and title – news of fraud or non-replicability, and warns ‘partisans’ against fuelling dangerous narratives, lest these undermine science. It remains unclear why journalist should take a lead from scientists about how to report about science’s misbehaviours, and why those fuelling these narratives are ‘partisans’, while those denying them are not.

A similar line is taken in an article (Fanelli, 2018) from Daniele Fanelli, who has been a rather coherent upholder of the no-systemic-crisis narrative (Fanelli, 2013). His position is that “the rising number of retractions is most likely to be caused by a growing propensity to retract flawed and fraudulent papers, and there is little evidence of an increase in the prevalence of misconduct” (Fanelli, 2013). Fanelli insists that a careful reading of the evidence points more to the heterogeneity among different research fields (Fanelli, 2010; Fanelli et al., 2017) than to a generalized state of disease. He argues in (Fanelli, 2018) that concerns about the consequences of abuse and misuse of the p-test are exaggerated¹. In his view the prevalence (the prior probability of a positive results) is in most mature fields as high as 50%, and hence the false discovery rate – a measure of the failure rate when using the p-test - is not as high as it is claimed. It is doubtful that this can be taken as a general rule in the face of the evidence (Shanks et al., 2015), when important statistical institutions (Wasserstein & Lazar, 2016) and statisticians have expressed and continue to express concern about the situation (Leek et al., 2017). Finally, Fanelli ignores the interplay between the ductility of statistical methods and the incentives to produce publishable results, which has been flagged by many as an important element of the problem (Gelman & Loken, 2013, 2014; Saltelli & Stark, 2018; Stark & Saltelli, 2018).

Normative elements are present in both Fanelli’s and Jamieson’s articles, e.g. for Fanelli:

The new “science is in crisis” narrative is not only empirically unsupported, but also quite obviously counterproductive. Instead of inspiring younger generations to do more and better science, it might foster in them cynicism and indifference. Instead of inviting greater respect for and investment in research, it risks discrediting the value of evidence and feeding antiscientific agendas.

Both pieces insist on the respect which is due to scientific research. But this element is extraneous to scientific ethos, suffices to think to the principle of organized scepticism (Merton, 1973), and appears closer to a religious view of science, including in the idea that doubters corrupt youth. Perhaps young scientists are more concerned by the proletarianization of research than by science being administered a rude medicine by the media and by science’s studies scholars.

Finally, John PA Ioannidis – an investigator who has done more than most to flag the reproducibility crisis (Ioannidis et al., 2005, 2014), notes (Ioannidis, 2018) that

...even well-intentioned academics, perceiving an attack on science, may be tempted to take an unproductive, hand-waving defensive position: “we have no problem with reproducibility”, “everything is fine”, “science is making progress”.

The piece from the National Association of Scholars (Randall & Welser, 2018) (Scholars in the following) argues that sloppy procedures are infecting our science, now victim of politicized groupthink and advocacy-driven science. The crisis is thus real, the emergency needs corrective action, and a list of measures is proposed which include the so-called transparent science proposals dear the US republican party, whereby agencies should only regulate on open, transparent and verifiable science. For example, the suggested Scholars’ list includes items to strengthen the power of industry against regulators such as:

31. Congress should pass an expanded Secret Science Reform Act to prevent government agencies from making regulations based on irreproducible research.

32. Congress should require government agencies to adopt strict reproducibility standards by measures that include strengthening the Information Quality Act.

However sympathetic one might wish to be to the Scholars’ arguments, the impression that transparency is being weaponized to political ends is difficult to resist, especially when reading the preface to the piece due to Peter Wood, NAS’ president. The problem we have with NAS is not just with the possibly disingenuous appropriation of the acronym of National Academy of Science, but rather with the scholars’ assimilation of bad science with advocacy, and of advocacy with an array of issue of the ‘progressive left’, including: “neo-Marxism, radical feminism, historicism, post-colonialism, deconstructionism, post-modernism, liberation theology, and a host of other ideologies”.

Note finally that NAS’ move to appropriate the crisis to political end is nothing new. The UK based Global Warming Policy

¹ For a reader not familiar with statistics or with hypothesis testing this free video from the journal The Economist is a brilliant plain-English illustration: <https://www.economist.com/graphic-detail/2013/10/21/unlikely-results>.

Foundation also presents a bleak picture of the peer review process to conclude (Laframboise, 2012):

“If half of published, peer-reviewed papers ‘may simply be untrue’, half of the papers cited by the IPCC may also be untrue.... Until key climate findings meet a higher standard than mere peer review, we cannot claim that our climate policies are evidence-based.”

Conservative’s moves to contrast the mainstream climate narratives are well documented (Mayer, 2017), as well as the crescendo war against regulators which has been waged first on uncertainty and transparency, since the Data Quality Act of 2001 (Michaels, 2008), and which at present targets reproducibility (Oreskes, 2018).

The pieces discussed above are emblematic in that a war on science which was anticipated (Saltelli & Funtowicz, 2016) appears now in course, at least in the US. Thus The Wall Street Journal (Wood & Randall, 2018) substantially endorses the Scholars’ reading, including in the need to limit regulations supposedly due to bad science, while a progressive observer (Schulson, 2018) notes “when does that criticism tip over into unwarranted skepticism — or even feed ideologically motivated attacks on researchers’ work?”

We note that in these debates everyone blames ‘activism’ or advocacy with scientists of the opposing faction.

2. The broader picture

Science is experiencing a crisis which is, on one hand, methodological, ethical and philosophical, and on the other political and institutional (Saltelli & Funtowicz, 2017a). The modern model of influence of science and technology on public policies has resulted in a situation where the crisis of the political system and that of science conflate one another – as witnessed by the post-truth, post-facts debates, challenging the arrangements whereby knowledge – in the form of science – and power legitimize one another (Benessia et al., 2016).

Science’s institutions have predominantly chosen to ignore the crisis (Saltelli & Funtowicz, 2017b), and to pretend that we are in a new phase of a different, long past war (Saltelli & Funtowicz, 2016); that between science (and reason) and anti-science (and obscurantism). This narrative blames the crisis on postmodern philosophers, oil friendly politicians, and other enemies of reason. Such a simplified reading –accompanied by an acritical call to the values of the Enlightenment (Pinker, 2018) – runs the risk of complacency, of ignoring the grave challenges facing societies and the self-destructive dynamics of science itself. Foremost the ‘no-crisis’ field ignores the structural coupling between science and other human and societal systems, such as education, policy, economy, even our psyche, all of which are differently entangled by the present predicaments: to exemplify, there is no way end to the saga of misuse of statistical tools without changing the way these are taught; no way we can fix science if we are afraid of threatening science’s funding. No solution in sight if we maintain as imperative to defend the privileged status of researchers as adjudicators of the truth and the good, or if we keep using science as an ersatz religion.

As per the causes of the crisis Mirowski (2011), has written convincingly of the relationship between the crisis and the neoliberal ideology, the commodification of knowledge & research and the dystopian degeneration of old ideas of science as a market; these ideas, popular during the cold war (POLANYI et al., 2018; Saltelli, 2017a), are now past their time.

Another way of reading the crisis sees science as victim of its own unfettered growth, and in need to be kept honest by technological, industrial or governmental command and control arrangements (Sarewitz, 2016). This reading neglects that the interest being served by science in this setting would be those of the technological or political masters, not of society at large. Crises as different such as “Insectageddon” (Monbiot, 2017), the disappearance of insects due to pesticides, and that of Facebook and Cambridge Analytica (Wade, 2018) skewing the results of political elections, both see science – of some sort, deployed against the common good. It appears that important asymmetries of power influence the use of science for policy (Madrick, 2016), and that regulatory capture or failure result in societies unable to regulate either Monsanto or Facebook.

3. Structural contradictions

For the philosopher of science Jerome R. Ravetz there has been an accumulation and maturation of structural contradictions in modern science (Ravetz, 2011), between its public image and public roles, between real and acknowledged uncertainty in science’s pronouncements, between technological progress and technological risk, and in its purported structural relation to democracy (Saltelli, 2017a). This is also the position of post normal science (PNS, see Box 1), whose proponents - Silvio Funtowicz and Ravetz himself, have been reflecting on the governance of science’s quality since at least four decades (Funtowicz & Ravetz, 1990; Ravetz, 1971). PNS’ mantra - as the science at play when facts are uncertain, stakes high, values in dispute and decision urgent (Wikipedia, 2018) - frequently appears in current debates about causes and potential solutions (Funtowicz & Ravetz, 1993).

What reading does post normal science offer of the present situation? For PNS powerful drivers are at play, and notwithstanding brave efforts to tackle the crisis reviewed in (Fanelli, 2018; Jamieson, 2018) the endgame looks far from reassuring, especially as these efforts mostly focus on the technical machinery of reproducibility, leaving the broader moral question of science unaddressed. A further erosion of trust in science can be expected, and the situation might become worse before it can become better (Saltelli, 2017b), due to a plurality of factors such as:

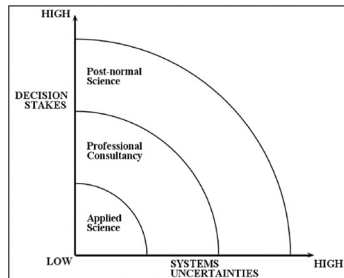
- The Darwinian fitness of bad-science to reproduce itself (Smaldino & McElreath, 2016);
- Its resilience, whereby even retracted papers keep faring better than their retractions long after publication (Banobi et al., 2011), and poor methodology persist, as noted in the case of statistics (Gigerenzer et al., 2015);
- Present day science’s systemic capacity to turn initiative to improve science’s conduct into their perverse opposite (Edwards & Roy, 2017).

Box 1

Post normal science.

Post normal science. An irritant or a solution?

Since “Science for the post-normal age” was published on FUTURES in 1993 (Funtowicz & Ravetz, 1993) by Silvio Funtowicz and Jerome R. Ravetz it has received about 4 thousand citations according to Google Scholar. While the assonance of post-normal with post-modern has gained the term its share of hostility, its mantra “facts uncertain, values in dispute, stakes high and decisions urgent”, and its iconic diagram are becoming accepted as a useful concept to ask pertinent questions at the science-policy interface.



As indicated by the diagram, PNS does not pretend to apply to (or replace) all of science’s quality control or governance structures. It becomes relevant in the presence of conflicted issues involving - according to a commentator, cases as disparate as “eradication of exogenous pests [...], offshore oil prospecting, legalization of recreational psychotropic drugs, water quality, family violence, obesity, teenage morbidity and suicide, the ageing population, the prioritization of early-childhood education, reduction of agricultural greenhouse gases, and balancing economic growth and environmental sustainability” (Gluckman, 2014). In these settings PNS often proceeds ‘*via negativa*’, e.g. by warning against the reduction of political/practical problems to technical ones, and against the artificial separation of facts and values at the science-policy interface. PNS promotes problem-solving by deliberative extended peer communities where different kinds of knowledge are brought to bear. Wikipedia hosts a reasonably compact introduction to PNS (https://en.wikipedia.org/wiki/Post-normal_science), with pointers to available resources.

The term science (or scientist) has perhaps become too broad as to be of practical use, describing a vague and ambiguous set of human endeavours. This hybrid is the source of confusion and possibly obfuscation. Who is a scientist? We crave the heroic and romantic figure, as Marc Edwards, who took up the cause of water activists in Flint (Michigan) (Hohn, 2016). Then there are figures such as Paolo Macchiarini (Carl, 2018), the reckless surgeon who killed some of his patients while protected by the shield of a powerful medical institution; that of Aleksandr Kogan, selling research data obtained from Facebook for profit to unscrupulous political ends (Wade, 2018); of Rick Mishkin, the economist satirized in the movie *Inside Job*². To pretend that these are just rotten apples in an otherwise enchanted garden – and that the evidence given by the media to these episodes is irresponsible as argued by Jamieson (2018) can be an understandable defensive position but does not advance a discussion which is becoming urgent (Saltelli & Funtowicz, 2017b).

4. A way forward?

While endorsing the existing efforts to fix the present reproducibility crisis, (Munafò et al., 2017) we believe that a radically new concept, practice, and ethos need to be imagined and acted, by scientists - who need to be clearer about what they can deliver and what they cannot, and by society, which must come to accept a more circumspect understanding of the role of science in informing societal and technological directions.

Science and policy institutions should be foremost concerned with remedying the ongoing drift in trust – whose effect is evidenced the proliferation of conspiracies theories - by rebalancing power asymmetries in the use of evidence (Laurens, 2017). At present the actors with the deepest pockets can buy the science they need, frame issues according to specific agendas and enforce these on the rest of society (Drutman, 2015; Laurens, 2017; Saltelli & Giampietro, 2017). This is done via pervasive practices such as e.g. ghost-writing (academicians signing scientific papers prepared by industry insiders) (Sismondo, 2009), (McHenry, 2010), influencing the debate on evidence-based policy, such as in the case of the Brussels Declaration (Bero, 2018; McCambridge et al., 2018), mobilizing Nobel prize laureates to defend a corporate line (Saltelli et al., 2017), and so on. In this asymmetric warfare corporations may become the main originator of the evidence available to policy, simply because politicians and their staffers lack the resources available to

² <https://www.youtube.com/watch?v=8IHvTKzfu8Q>.

corporations. In the US corporate interest can spend on lobbying \$34 for each dollar spent by diffuse interest and unions combined (Drutman, 2015), and the situation is not better in Europe, especially due to the intensity of lobbying power which the concentration of EU institutions in Brussels facilitates (Laurens, 2017).

Drutman (2015), an American scholar, suggests to fund institutions able to alleviate this asymmetry, which concern both the balance of power and of science-based knowledge. Among his proposals, that of an Office for Public Lobbying, or some structured mechanism to give citizens the same level of protection afforded to indigent defendants by the courts. Drutman argues that these measures are urgent, due to the systemic and autocatalytic nature of lobbying which is both persistent (sticky) and increasing in scope and volume.

At the same time scientists should abandon an idealized vision of Enlightenment and engage with the problems. As noted by a recent editorial in *Nature* (Anonymous, 2017), “It is not Trump that scientists must respond to. The real question is what science can do for the people who voted for him”.

The media should continue to do what they do best – exposing problems - without fears of disrespecting science. Last in a long series, the Macchiaroni scandal was exposed by investigative journalism, after whistle-blowing scientists were silenced by the scientific apparatus (Carl, 2018).

It would be a disgrace if the present science war – mostly evident in the US – were to lead to the same partisan polarization in the rest of the planet, thus entrenching conservatives and progressives under the crisis/no-crisis banners.

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References

- Anonymous (2017). Researchers should reach beyond the science bubble. *Nature*, 542(February (7642)), 391.
- Banobi, J. A., Branch, T. A., & Hilborn, R. (2011). Do rebuttals affect future science? *Ecosphere*, 2(March (3)), art37.
- Benessia, A., et al. (2016). The rightful place of science: science on the verge. Consortium for science. *Policy & Outcomes*.
- L. Bero, “Ten tips for spotting industry involvement in science policy.,” *Tob. Control*, p. tobaccocontrol-2018-054386, June. 2018.
- Carl, Elliott (2018). *Knifed with a Smile*. New York Review of Books 05-Apr.
- Drutman, L. (2015). *The business of America is lobbying : How corporations became politicized and politics became more corporate*. Oxford University Press.
- Edwards, M. A., & Roy, S. (2017). Academic research in the 21st century: Maintaining scientific integrity in a climate of perverse incentives and hypercompetition. *Environmental Engineering Science*, 34(January (1)), 51–61.
- EPA, O. U. S., & O.A, O. E. A. E. E. (2018). *EPA Administrator Pruitt Proposes Rule To Strengthen Science Used In EPA Regulations*. EPA, Press release 24-Apr.
- Fanelli, D. (2018). Opinion: Is science really facing a reproducibility crisis, and do we need it to? *Proceedings of the National Academy of Sciences of the United States of America*, 115(March 11), 2628–2631.
- Fanelli, D. (2013). Why growing retractions are (mostly) a Good sign. *PLoS Medicine*, 10(December 12), e1001563.
- Fanelli, D. (2010). Positive’ results increase down the hierarchy of the sciences. *PLoS One*, 5(April (4)), e10068.
- Fanelli, D., Costas, R., & Ioannidis, J. P. A. (2017). Meta-assessment of bias in science. *Proceedings of the National Academy of Sciences of the United States of America*, 114(April (14)), 3714–3719.
- Funtowicz, S., & Ravetz, J. R. (1993). Science for the post-normal age. *Futures*, 25(September (7)), 739–755.
- Funtowicz, S., & Ravetz, J. R. (1990). *Uncertainty and quality in science for policy*. Kluwer: Dordrecht.
- Gelman, A., & Loken, E. (2013). *The garden of forking paths: Why multiple comparisons can be a problem, even when there is no ‘fishing expedition’ or ‘p-hacking’ and the research hypothesis was posited ahead of time*. http://www.stat.columbia.edu/~gelman/research/unpublished/p_hacking.pdf.
- Gelman, A., & Loken, E. (2014). The statistical crisis in science. *American Scientist*, 102(6), 460.
- Gigerenzer, G., Marewski, J. N., & Science, S. (2015). *Journal of Management*, 41(February (2)), 421–440.
- Gluckman, P. (2014). Policy: The art of science advice to government. *Nature*, 507(March (7491)), 163–165.
- Harris, R. F. (2017). *Rigor mortis : How sloppy science creates worthless cures, crushes hope, and wastes billions*. Basic Books.
- Hohn, D. (2016). *Flint’s Water Crisis and the ‘Troublemaker’ Scientist*. New York Times Magazine 16-Aug.
- Ioannidis, J. P. A. (2018). All science should inform policy and regulation. *PLoS Medicine*, 15(May (5)), e1002576.
- Ioannidis, J. P. A., Chen, J., Kodell, R., Haug, C., & Hoey, J. (2005). Why Most published research findings are false. *PLoS Medicine*, 2(August (8)), e124.
- Ioannidis, J. P. A., Forstman, B., Boutron, I., Yu, L., & Cook, J. (2014). How to make more published research true. *PLoS Medicine*, 11(October (10)), e1001747.
- Ioannidis, J. P. A., Stanley, T. D., & Doucouliagos, H. (2017). The power of bias in economics research. *The Economic Journal*, 127, F236–F265.
- Jamieson, K. H. (2018). Crisis or self-correction: Rethinking media narratives about the well-being of science. *Proceedings of the National Academy of Sciences of the United States of America*, 115(March 11), 2620–2627.
- Laframboise, D. (2012). *Peer review — Why skepticism is essential, the global warming policy foundation (GWPF) report*.
- Laurens, S. (2017). *Lobbyists and bureaucrats in Brussels : Capitalism’s brokers*. Routledge.
- Leek, J., McShane, B. B., Gelman, A., Colquhoun, D., Nuijten, M. B., & Goodman, S. N. (2017). Five ways to fix statistics. *Nature*, 551, 557–559.
- Madrick, J. (2016). *How the Lobbyists Win in Washington*. New York Review of Books 07-Apr.
- Mayer, J. (2017). *Dark money : the hidden history of the billionaires behind the rise of the radical right*. Anchor.
- McCambridge, J., Daube, M., & McKee, M. (2018). Brussels Declaration: a vehicle for the advancement of tobacco and alcohol industry interests at the science/policy interface? *Tob. Control*(June) p. tobaccocontrol-2018-054264.
- McHenry, L. (2010). Of sophists and spin-doctors: Industry-sponsored ghostwriting and the crisis of academic medicine. *Mens Sana Monographs*, 8(January (1)), 129.
- Merton, R. (1973). *The sociology of science: Theoretical and empirical investigations*. University of Chicago Press.
- Michaels, D. (2008). *Doubt is their product: How industry’s assault on science threatens your health*. Oxford University Press.
- Mirowski, P. (2011). *science-mart, privatizing American science*. Harvard University Press.
- Monbiot, G., “Insectageddon: farming is more catastrophic than climate breakdown,” *The Guardian*, 20-Oct-2017.
- Munafò, M. R., et al. (2017). A manifesto for reproducible science. *Nat. Hum. Behav.* 1(January), 1–9.
- Oreskes, N. (2018). Beware: Transparency rule is a trojan horse. *Nature*, 557(May 7706), 469.
- Pinker, S. (2018). *Enlightenment now : The case for reason, science, humanism, and progress*. Random House.
- Polanyi M., Ziman J., and Fuller S., *The republic of science: its political and economic theory* *Minerva*, I (1) (1962), 54-73, *Minerva*, vol. 38. Springer, pp. 1–32.
- Randall D. and Welsler C., *The irreproducibility crisis of modern science: Causes, consequences, and the road to reform* 2018.
- Ravetz, J. R. (2011). Postnormal science and the maturing of the structural contradictions of modern European science. *Futures*, 43(March (2)), 142–148.

- Ravetz, J. R. (1971). *Scientific knowledge and its social problems*. Oxford University Press.
- Saltelli, A., "A scientists' march on Washington is a bad idea – Here's why," *The Conversation*, 21-Apr-2017.
- Saltelli, A., "Science's credibility crisis: why it will get worse before it can get better," *The Conversation*, 09-Nov-2017.
- Saltelli, A., & Funtowicz, S. (2016). *Science wars in the age of Donald Trump*. *The Conversation*, 16-Nov.
- Saltelli, A., & Funtowicz, S. (2017a). What is science's crisis really about? *Futures*, 91, 5–11.
- Saltelli, A., & Funtowicz, S. (2017b). *To tackle the post-truth world, science must reform itself*,". *The Conversation*, 27-Jan.
- Saltelli, A., & Giampietro, M. (2017). What is wrong with evidence based policy, and how can it be improved? *Futures*, 91(February), 62–71.
- Saltelli, A., & Stark, P. (2018). Fixing statistics is more than a technical issue. *Nature*, 553(January (7688)), 281.
- Saltelli, A., Giampietro, M., & Gomiero, T. (2017). Forcing consensus is bad for science and society. *Conversation*(May (12)).
- Sarewitz, D. (2016). Saving science. *New Atl.* 49, 4–40.
- Schulson, M. (2018). *A Remedy for Broken Science, Or an Attempt to Undercut It?* undark.org, Apr-.
- Shanks, D. R., et al. (2015). Romance, risk, and replication: Can consumer choices and risk-taking be primed by mating motives? *Journal of Experimental Psychology: General*, 144(December (6)), e142–e158.
- Sismondo, S. (2009). Ghosts in the machine. *Social Studies of Science*, 39(April (2)), 171–198.
- Smaldino, P. E., & McElreath, R. (2016). The natural selection of bad science. *Royal Society Open Science*, 3(160384).
- Stark, P., Saltelli, A (2018). Cargo-cult statistics and scientific crisis Significance. (online version) 05 July 2018, <https://www.significancemagazine.com/2-uncategorised/593-cargo-cult-statistics-and-scientific-crisis>.**
- Wade, M. (2018). *Psychographics: the behavioural analysis that helped Cambridge Analytica know voters' minds*. *The Guardian*, 21-Mar.
- Wasserstein, R. L., & Lazar, N. (2016). The ASA's statement on p-values: Context, process, and purpose. *Am. Stat.* 70(April (2)), 129–133.
- Wikipedia, Post-normal science 2018. [Online]. Available: https://en.wikipedia.org/wiki/Post-normal_science.
- Wood, P., & Randall, D. (2018). How bad is the government's science? *Wall Street Journal*(April).