

From sociology of quantification to ethics of quantification

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Quantifications are produced by several disciplinary houses in a myriad of different styles. The concerns about unethical use of algorithms, unintended consequences of metrics, as well as the warning about statistical and mathematical malpractices are all part of a general malaise, symptoms of our tight addiction to quantification. What problems are shared by all these instances of quantification? After reviewing existing concerns about different domains, the present perspective article illustrates the need and the urgency for an encompassing ethics of quantification. The difficulties to discipline the existing regime of numerification are addressed; obstacles and lock-ins are identified. Finally, indications for policies for different actors are suggested.

1. Give me a number!

Numbers, visible and invisible, pervade our life, dominate the language of our communication, and accelerate all our transactions. What price is being paid?

At the time of writing the present work, uncertainty, precaution, and governance are the keywords describing how COVID-19 emergency is challenging political questions of security and health in the era of big data. In this context, numbers are very much in demand, and expected from science.

According to The New York Times (Landler and Castle 2020) the report which purportedly “jarred the U.S. and the U.K. to Action”, from the Imperial College in London (Ferguson et al.

2020), warned about the possibility of 510,000 deaths in Britain and 2.2 million in the US. How could such a two-digit precision be obtained? Known uncertainties include the prevalence of the virus in the population; the number of asymptomatic cases and their infectiveness; the behaviour and resilience of acquired immunity; the way the flue will react to the oncoming summer and to the next winter; the time needed to make a vaccine globally available; how the emergency will affect non-COVID patients, and how individuals will adapt their behaviour to the new situation and containment measures.

The report from the Imperial College explains that the calculation corresponds to the do-nothing scenario, and comes from a model described in a Nature paper (Ferguson et al. 2006b) and associated online supplementary information (Ferguson et al. 2006a). The uncertainty in the prediction was assessed moving just one uncertain factor, a strategy bound to grossly underestimate the uncertainty when the model is nonlinear and nonadditive (Saltelli and Annoni 2010; Saltelli et al. 2019), as is likely the case for epidemiological models, due to the exponential term(s) in the equation.

An intense debate in the media (Steerpike 2020; Fund 2020) and social mediaⁱ ensued about the scarce transparency of the Imperial College model, and its previous performance in the case of the BSE and foot and mouth disease documented in (Mansley et al. 2011; Kitching, Thrusfield, and Taylor 2006).

As noted, more realistically, by Anthony Fauci – a member of the White House Coronavirus Task Force at the time of the present work, in his reply to a politician insisting for a number of deaths, “There is no ‘number-answer’ to your question” (Fauci 2020).

Nassim Nicholas Taleb and Yaneer Bar-Yam go further in their indictment of poor use of mathematical modelling in the context of the UK pandemic experience, suggesting that modelling and policy making are two sources of error in the UK action. They note that “[I]f we base our pandemic response plans on flawed academic models, people die” (Taleb and Bar-Yam 2020). The subject of modelling work for COVID-19 was the subject of several commentaries (Rhodes and Lancaster 2020; Pielke 2020), including one involving the authors of the present work in the journal Nature (Saltelli, Bammer, et al. 2020b). Here we stressed that modelling is a social activity and that more inclusive societal negotiations are needed in the framing of these mathematical objects.

The pandemic shows how numbers and their uncertainty – if not properly mastered - may play a dysfunctional role at the science policy interface (Saltelli, Bammer, et al. 2020b; Bradshaw and Borchers 2000).

The pandemic has also shown that the act of quantifying, either by a model or by an algorithm, increasingly nourishes the science–policy interface with the opportunity to outsource decision-making authority to number-based decision-making (Danaher et al. 2017), when momentous political decisions are delegated to the purported neutrality of model generated numbers (Saltelli, Bammer, et al. 2020b).

There is, therefore, a circularity between numbers, models, algorithms and the interface between science and politics. In this perspective, the last decade has seen a growing critical thinking about a crisis in the workings of science - the so-called reproducibility crisis (Saltelli and Funtowicz 2017; Saltelli 2018). One of the many dimensions of this crisis is related to its ethical dimension, in the relationship between poor reproducibility and a perverse system of incentives (Smaldino and McElreath 2016; Edwards and Roy 2017). A sectors hit by the reproducibility crisis, and the first where the alarm was sounded (Begley and Ellis 2012), is that of biomedical research (Harris 2017; Ioannidis 2005, 2016), already affected by a collapse in trust (Goldacre 2012). This should be borne in mind now that the world waits for a COVID-19 vaccine.

Connecting this growing critical thought about scientific problems to ethics of quantification shows that a multitude of unintended effects, lock-ins and path dependencies, are worth paying attention to.

If one reads the present context with the lenses of social system theory, then one can take the mediatization of science (Scheufele 2014), its commodification (Mirowski 2011) and politicization (Pielke, Jr 2007)– as a consequence of the structural coupling of different systems – economy, science, media, policy. As per this theory, due to the German sociologist Niklas Luhmann (Moeller 2006; Luhmann 1995), each system communicates using its own code, true/false for science, profit/loss for the economy, new/no-news for the media and so on. For the authors in (Saltelli and Boulanger 2019), society is confronted with a situation where science’s code true/false is corrupted by those of the other systems, such as profit/loss, news/no-news, and finally by that of technology: functions/doesn’t-function. In this scenario media’s appetite for quantified information accelerates a process of pervasive quantification,

intended both as the production of more numbers, and the use of more algorithms in the social media.

As noted in (Saltelli 2020), finding commonalities in the undesired aspects of different forms of quantification can help chart the problem, and bring some perspective to scholars involved in different aspects of this discussion.

2. Numbers, models, algorithms, how different, how similar

What qualities are specific to rankings, or indicators, or models, or algorithms? What does quantification share with related concepts like commensuration or categorization? (Popp Berman and Hirschman 2018)

As algorithms and Big Data populate ever more deeply our life, following the evolution of what has been variously called platform capitalism (Lanier 2006) or surveillance capitalism (Zuboff 2019), decisions arrived at by computation may come to pose important societal threats (O'Neil 2016).

Quantifications seem to be the leading language used to deal with and solve different aspect of social and political life, even when this dissolves the meaningfulness of the number themselves, as when the news about the pandemic reports number of deaths, or worse of infected people, with the unbelievable precision of three, four, even five significant digits.

It becomes hence urgent for society to develop a better understanding of, adaptation to and defence from, a pervasive datafication. The exigency of policy to achieve efficiency and certainty through the instrument of quantification should be kept under societal control, lest the complexity of models, algorithms or rankings becomes an end to itself, used instrumentally to transform political problems into technical ones. It might be that the new, post-pandemic normal, will have to include a new maturity in the relationship between numbers and society.

It must be stressed here that there are different quantification tools and methods with distinguished social, political and economic impact: an algorithm embedding prejudices is different from a poorly designed statistical analysis, from a mathematical model predicting the unpredictable, or from the pervasive ranking of countries, cities or universities. Inequality embedded in algorithm may affect members of minority groups (ethnic, racial, sexual,

disability-related, etc.) (Danaher et al. 2017), with a long chain of impacts. A biased algorithm can inflict longer sentences to coloured people or simply to people living in a poor neighbourhood (O’Neil 2016; Muller 2018). A poorly designed statistical analysis for medical treatments could squander billions and kill thousands (Harris 2017). Poor modelling may lead to wrong, or simply unjustified, political choices (Saltelli 2019; Saltelli, Bammer, et al. 2020b, 2020a). The proliferation of rankings of universities has profoundly altered higher education, making it into a global market and dramatically increasing prices for students and their families (O’Neil 2016; Muller 2018). The list of examples could continue (Saltelli 2020). Still, as argued in the present work, the diversity in the various families of quantification hides important commonalities.

It should also be stressed that a list of perverse quantification can be contrasted with a list of virtuous ones. These come most often from the field of physics than from the more complex fields of medicine or social sciences. Thanks to clever modelling NASA scientists could position around Mercury the probe MESSENGER, launched in 2004, after five billions miles and six ½ years (Kay and King 2020).

Models for weather forecast are an example where a mutual process of domestication has taken place between models and society. By producing useful short-term predictions constantly updated by new information, and by communicating uncertainty carefully, these models make it normal for us to read on our mobile that tomorrow will be mostly sunny with a 20 per cent chance of rain (Lazo, Morss, and Demuth 2009). From agriculture to transport to energy, virtually all sectors of the economy benefit from these models (Sarewitz, Pielke, and Byerly 2000). Weather forecasts become controversial only under condition of extreme political interference, as shown by the recent story of hurricane Dorian in the US (Law and Martinez 2020), or when high-stakes events, such as storms or flooding, complexify the transmission from the technical knowledge of meteorologists to the takers of momentous political decisions, such as e.g., evacuation for coastlines or cities (Sarewitz, Pielke, and Byerly 2000; Pielke et al. 2002). Hurricanes and pandemics are situations “when facts are uncertain, stakes high, values in dispute and decisions urgent”, according to the mantra of post-normal science (Funtowicz and Ravetz 1993). COVID-19 illustrates perfectly the mutated conditions of operation of science when moved from the normal to the post-normal regime (Waltner-Toews et al. 2020); under these circumstances, when models impact directly societal decisions, their use needs better political and societal coping strategies (Saltelli, Bammer, et al. 2020b).

Sheila Jasanoff, identifies two opposing classes of modelling: ‘technologies of hubris’ and ‘technologies of humility’(Jasanoff 2003). Developed to reassure the public, and “to keep the wheels of science and industry turning”, the technologies of hubris include quantifications such as risk assessment and cost benefit analysis whose purpose is to promise a chance of management and control, even in areas of great uncertainty such as climate change. The promise is reinforced by claims of neutrality, rigour and objectivity, but these come, for Jasanoff, with important limitations, i.e. in generating overconfidence thanks to the appearance of exhaustivity, pre-empting political discussion of what remain outside these quantifications, and remaining limited in the capacity of these technologies to internalize challenges that arise outside their framing assumptions. All these remarks have been vindicated – in the opinion of the authors of the present work – by the numbers populating the present pandemic (Saltelli, Bammer, et al. 2020b). Calls for humility in relation to using mathematical model (Sridhar and Majumder 2020) come with disputes where models become the target of political attack (Pielke 2020). Some authors (Rhodes and Lancaster 2020) speak of “mathematical models as public troubles”.

Adopting “technologies of humility” (Jasanoff 2007) would entail to reflect on the sources of ambiguity, indeterminacy and complexity, to bring out the ethical dimensions of problems, and to identify winners and losers in the distributions of costs and benefits – focusing on the most vulnerable. Most importantly, for Jasanoff (Jasanoff 2003), society should identify those factors which either deter or encourage learning.

It is perhaps useful to note that the aspects of quantification which might be called hubristic enjoy in our society an privileged status and popularity, suffice to consider the role of intellectual such as Cass Sunstein (Matthews 2018), and Steven Pinker (Pinker 2018). The Panglossian numbers of the latter reassure us that all is well (Gray 2018), while the cost benefit analyses and nudging of the former ensure that – once society is given the right facts, in numerical form, disagreement will dematerialize, as “the issues that most divide us are fundamentally about facts rather than values” (Matthews 2018). For example, in relation to COVID-19, the Washington Post notes (Frankel 2020) that if we adopt a cost-benefit analysis using as a yardstick concepts such as the value of a statistical life (VSL, see Section 6), this would force society to confront reality in a more precise way; the alternative to using these tools, admonish the Washington Post, is to be left to gut feelings, educated guesses or political arguments (Frankel 2020).

3. A fragmented landscape

Quantifications are produced by several disciplinary houses in a myriad of different styles. What problems are shared by all these?

How, where and what is quantified? From education to finance, from criminal justice to global governance, from the economy to the environment, all fields are colonized by numbers. Mathematical and statistical models, indicators, metrics and algorithms of various nature and complexity are used to maximize efficiency, to measure profit, sustainability, decarbonisation, the achievement of objectives, the ratings of cities or restaurants. They can give a price to financial products which only initiates can understand (Porter 2012), and which have the power to collapse the economy (Wilmott and Orrell 2017; Salmon 2009).

For some scholars, humanity is now “entering an era of widespread algorithmic governance” (Kitchin 2017). Speed, efficiency, comprehensiveness and fairness are some positive properties invoked in favour of algorithmic governance. At the same time, this increasing complexity of algorithms comes in the form of black boxes (Danaher et al. 2017), where clarity is sacrificed, because although algorithms have the power to act upon data and make decisions, they are largely beyond query or question (Kitchin 2017; O’Neil 2016), thus foregoing the properties of comprehensiveness and fairness.

What kind of ethical reflection is going on these topics? Indeed, a lot, though in a fragmented landscape.

- Ethics of AI has become a field of its own, with both a rich literature, institutional initiatives (High-Level Expert Group on Artificial Intelligence 2019), including from the Holy See (Copestake 2019).
- In the discipline of statistics the community is moored in an internal ‘statistics war’ about the fundamental concepts to be used or taught (Gelman 2019).
- Abuse and misuse of metrics – from the Goodhart’s law to our days, is also a field with a long tradition of investigation (Muller 2018).
- In mathematical modelling the situation is at the same richer and more confused, owing to mathematical modelling not being a discipline (Saltelli 2019; Saltelli, Bammer, et al. 2020b).

- Rankings, inferences, decisions, are all different output of these activities, which in some cases do not even bring to the surface a number. Yet these are all instances of quantification.

Wendy Espeland and Mitchell Stevens (Espeland and Stevens 2008) draw attention to the spread of quantification and the significance of new regimes of measurement, where democracy, merit, participation, accountability and even “fairness” are to be discovered and appreciated via numbers. These authors investigate five key dimensions of quantification

- the work it requires, e.g., in relation to the need for “well-funded bureaucracies with highly trained administrators”;
- its reactivity, in that “turning qualities into quantities creates new things and new relations among things”;
- its tendency to discipline human behaviour, e.g., by practices which define what is appropriate, normal;
- its polyvalent authority, in that quantitative authority confer epistemic authority, and ultimately power (Porter 1995);
- its aesthetics, in relation to the craft skills and evolving fashions related to making numbers compelling, and in a sense, beautiful.

The authors conclude with the pressing recommendation to move from a sociology of quantification to an ethics of numbers. This descends from the realization that quantification is fundamentally a social activity, and for this its ethical implications should be considered explicitly and transparently.

While sociology of quantification has received a considerable boost in the last decade – see the review in (Popp Berman and Hirschman 2018), ethics of quantification is still fragmented in different realms of quantification.

The COVID-19 pandemic offers perhaps the appropriate moment for this discussion, now that the discussion about COVID-19 is formulated in the jargon of mathematics and models (Rhodes, Lancaster, and Rosengarten 2020), with expression such as ‘flatten the curve’ entering into everyday language.

Said otherwise, the present moment of intense reciprocal domestication between society and the numbers of the pandemic may bring us closer to the mature use of quantification exemplified above for the case of weather predictions.

4. Concerned readings: who is alarmed?

Voices of concern about different aspects of quantification

As noted by Cathy O’Neil (O’Neil 2016), one deplorable use of algorithms/mathematics in the guise of operational research, is making labour conditions harder, by a scheduling which optimizes the employer benefits. She mentions ‘clopening’, the practice whereby the same worker is responsible for closing a public exercise in the night and open it in the morning, and how these practices make it impossible for an employee to plan care for children and elderly, for studying, for having a life.

Similar, and possibly more drastic conclusions are reached by Alain Supiot (Supiot 2007), a jurist, for whom the numerification of society has created a system where algorithms replace laws, and the labour market has transformed from Taylorian - where the labourers sold to the employers hours of labour – to cybernetic, whereby thanks to the governing by objective, the mobilization of the workers is total, in a homeostatic system where their performance is constantly measured. In this system, argues Supiot, any possibility of appeal and negotiation is lost, the law loses its heteronomy, human solidarity is eroded, as the fellow worker becomes a competitor, and the individual is left to seek the protection of the more powerful in order to survive; in other words, a re-feudalization of society.

A complementary reading of the situation is offered by the French movement of ‘*statactivistes*’ (I. Bruno, Didier, and Prévieux 2014), which reconnects to a rich tradition of sociology of numbers (Pierre Bourdieu, Alain Desrosieres) to fight numbers with numbers under the slogan ‘another number is possible’. As shown by the many compelling examples in the book and articles of the *statactivistes* (I. Bruno, Didier, and Prévieux 2014; Isabelle Bruno, Didier, and Vitale 2014) the fight against a dystopian use of quantification is not the end of quantification, but its correct use disciplined by just laws. The rich repertoire of strategies deployed by the *statactivistes* includes ‘statistical judo’, a technique of self-defence against invasive measures of performance. *Statactivistes* also demonstrate examples of how unjust metrics can be

deconstructed and replaced with a fairer one – e.g., in the measurement of poverty (Concialdi 2014), and how hidden pathologies of society can be detected by statisticians - dramatic the example of suicides at France Telecom as a result of a drastic restructuring of the company, see also the discussion in (Saltelli 2020).

At Cardiff University in the UK, a Data Justice Lab examines the relationship between datafication and social justice, investigating the politics and the consequences of big data and data-driven processes (Cardiff University 2020).

Other virtuous examples of data activism are described by O’Neil (O’Neil 2016), p.91-92, where ‘Hackathons’ are the occasion for the opening of the black box of algorithms, to detect embedded racial prejudice, e.g., in the software used by the police. Other relevant example of activism are models to combat gerrymandering in the US, and to defend in the wider world the integrity of the voting process in elections (Lindeman and Stark 2012).

A form of societal activism on the relation between models and society is offered by Tomas Pueyo, not an epidemiologist, who maintains a blog for COVID-19 epidemiological models and explains in plain-language the implications of model uncertainties for policy options (Pueyo 2020), along the lines of ‘modelling as a social activity’ discussed in (Saltelli, Bammer, et al. 2020b).

5. Reasons for an ethics of quantification

Why does society need an encompassing ethics of quantification? Why it is urgent now?

As noted in Section 3, for Espeland and Stevens (Espeland and Stevens 2008) a sociology and an ethics of numbers is needed due to the spread of quantification and the significance of new regimes of measurement. In a previous work from one of the authors (Saltelli 2020) the case for an ethics of quantification (EoQ) is made as follows:

- An ethics of quantification is needed because of the symbiotic relationship between quantification and trust (Porter 1995).
- It is a defence against statistical abuses perpetrated by public or private actors (I. Bruno, Didier, and Prévieux 2014).

- It can oppose consequentialism in scientific quantification – meaning by this the instrumental production of numbers just because there is a cause or an audience to serve, irrespective of the numbers’ quality. Consequentialism is typically associated with an optimistic view of how the ‘good’ can be neatly computed (Saltelli 2020), and with the ‘modelling hubris’ often met in quantitative studies (Saltelli 2019; Saltelli, Bammer, et al. 2020b).
- It helps to apportion responsibilities and to act on them when metrics produce unintended or otherwise undesirable effects (O’Neil 2016; Muller 2018).
- An ethics of quantification can assist in realizing that “The technique is never neutral” (Saltelli, Benini, et al. 2020), meaning by this that the outcome of a policy study can be decided in advance just by the choice of the experts and disciplines called to adjudicate it (Beck 1992). An important instance of this is when a political issue is presented/transformed into a technical one (Ravetz 1971). Thus, an ethics of quantification can help to make the relationship between a quantification and the associated context and purpose more stringent (Zyphur and Pierides 2017).
- The fragmented nature of ethics efforts in different disciplines discussed above calls for an encompassing ethical effort.

To this list, a more general concern can be added for the way numerification may change the nature of a discipline. The point has been made repeatedly for the mathematization of economics (Reinert 2000; Mirowski 1991) and for sociology falling prey of statistical rituals (Gigerenzer and Marewski 2014).

For the authors in (Sareen, Rommetveit, and Saltelli 2020) the main reason to call for an ethics of quantification is related to the two faces of quantification: one of illumination and one of obfuscation. Social actors producing quantification may strategically illuminate those aspects that can be socially legitimated, while obfuscating those that cannot. An example is the use of an AI assisted census to purportedly increase the legitimacy of a biometricising governance regime, while at the same time some citizens are not allowed to register, becoming invisible. This is the case of Aadhaar system in India (Sareen, Rommetveit, and Saltelli 2020).

This debate has become all the more urgent at the moment of the pandemic. When a set of numbers – deaths and infections in the present case, establish itself at the centre-stage, other possible numbers and stories may be neglected, including the losses for the more vulnerable

economic subjects, the loss of rights such as that to education, to health (for other than COVID-19 issues) and to civil liberties (Didier 2020; Foucault et al. 2020).

6. Obstacles

Why the battle to discipline a pervasive datafication of the world will be hard

A program such as one of increased attention to the ethics of quantification is made arduous by a variety of factors. One is the prevailing techno-optimistic paradigm, whereby normative bias and controversy dissipate against the light of well-crafted quantification, as argued by Cass Sunstein (Matthews 2018), while for Aaron Bastani (Bastani 2019) the new era of big data and artificial intelligence will present us with an era of abundance, a “Fully Automated Luxury Capitalism”.

Related to the pandemic, while concepts such as value of a statistical life are considered by many authors controversial even within their ‘home’ in actuarial sciences, when applied, in the setting compensatory damages (Viscusi 2008), e.g. in case of airplane crashes (Linshi 2015), they still have currency in global socio-economic and health contexts, and are used in (Thunstrom et al. 2020) to conclude that social distancing in the US will lead to net benefit of about \$5.2 trillion. In spite of the apparent objectivity of VSL, even within the administration of the United States different regulatory agencies use different values of VSL (Viscusi 2008).

As an example of resistance to datafication, the addictive nature of algorithms and AI in the new social media is denounced by Jaron Lanier, who suggests to his readers that they should close all their social accounts immediately (Danaher et al. 2017).

According to Rob Kitchin (Kitchin 2017), algorithms create capital, steer behaviour, identify people, and multiply themselves in a growing web of applications. They hence represent non-neutral practices corresponding to specific political economies and cultures. The working of algorithms is thus not ‘apolitical’. For Lucas Introna (Introna 2016) the new regimes of quantification allows a group of state and private actors to increase their interconnectivity at the expenses of their subjects — be these customers, consumers, citizens, migrants, tourists, suspects, students, friends, colleagues, and many others. These considerations suggest the existence and reinforcement of lock in and path dependence processes.

Lock-in are also evident in many strands of occupation. As researchers, the authors are well aware of the damage brought about by the system of evaluation of research quality based on

metrics such as the impact factor or the Hirsh factor (Wilsdon 2016); yet researchers can no more easily stop using these measures than deans can stop checking the position of their departments and universities in international rankings.

Whatever course society takes it will have to contend with the pessimism of the Collingridge dilemma (Collingridge 1980): it is arduous to control a technology, as it is impossible to know in advance its negative effects, and when the consequences become evident, it might be too late to intervene.

7. Some emerging Implications for policy

What should be done?

Since the gist of the present work is in the commonality of the issues met in the different families of quantification, the authors do not repeat in this section all the policy initiatives which are already ongoing in existing fields where the discussion is more advanced, as for example in the ethics of artificial intelligence and algorithms, see a recent review in (Cath et al. 2018), or in the domain of official statistics, where codes of good practices have existed for a long time.

The focus here is on the more general initiatives which could be taken on numbers in general. Referring to AI the authors in (Cath et al. 2018) note that “We are creating the digital world in which future generations will spend most of their time”, and the same can be said of the present pattern of datafication of everyday life.

In this respect holistic approaches are needed. For Shoshana Zuboff “If the digital future is to be our home, then it is we who must make it so”, (Zuboff 2019), p.21. Among our most urgent tasks, for this author, is the “naming of the unprecedented”, i.e. to describe and draw attention of the singularity of the present transition in the battle against what she calls surveillance capitalism. There are surprising analogies between these sentiments and those expressed by scholars of different orientation, from the jurists (Supiot 2007) to the data scientists (O’Neil 2016) to the *Statactivistes* (I. Bruno, Didier, and Prévieux 2014), to the historians (Muller 2018; Porter 2012), and many others.

Hence, the next sections describe a few suggestions for specific actors.

Role of organized labour

If this will be a collective fight of ‘us the people’, the role of unions and other social actors will be of paramount importance. The example of the fight of the *statactivistes* with the official French statistical institute INSEE to change the way of measuring poverty is instructive (Concialdi 2014); the fight would not have been possible without the help from the unions which put the problem on the table and assisted the *statactivistes* in their battle. The COVID-19 pandemic offers to organized labour a natural experiment about which workers fall through the net of welfare systems, how to measure and compensate the performance of all those workers who have made social distancing possible (ILO 2020), as well as to measure the many ways in which the pandemic increase existing inequalities (Macfarlane 2020).

Role of institutions

For Zuboff, the need to fight the “unprecedented” totalitarian ambitions of surveillance capitalism and its attempt to dominate human nature implies the capacity for society to discover that all is not well (Zuboff 2019). While Zuboff is quite accurate in the diagnosis of the challenge, she is in general vague in her conclusions as to what actions this new indignation should lead to (di Bella 2019). In our opinion an important ingredient in the battle of ideas she advocates is to give civil society and institutions the means to source their evidence independently to contrast the important devices of persuasion and lobbying of surveillance capitalists. According to David Michaels (Spencer 2020), discussing how to contrast the power of lobbies, “we need independent science paid for by the producers”, meaning by this that part of the cost of this increased surveillance (or anti-surveillance?) should be brought by those who needs to be regulated – in this case the producers of opaque algorithms and ratings. It is important to avoid the trap whereby “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” (Saltelli 2018).

In order to tackle this important challenge to the future of our societies the recipe of Lee Drutman (Drutman 2015) is that of an ‘Office for Public Lobbying’. The idea would be to offer citizens the same protection afforded to indigent defendants by the courts. In this respect – in a US perspective, the US Office for Technological Assessment (OTA) can be remembered. Eliminated in 1995 by a conservative legislature (Chubin 2001), it offers a cautionary tale. “A moment’s thought brings to mind a dozen or more subjects where an analytical agency like

OTA could be of use today”, notes Adam Keiper (Keiper 2004) in 2004. In 2020, an OTA-like agency would not be without work.

Europe and the agenda for Responsible Research and Innovation (RRI)

In Europe the movement of Responsible Research and Innovation (RRI), part of the European Commission Horizon 2020 research strategy, has contributed to a reflection on the ‘right impacts’ of research, as well as on research’s governance, responsiveness, integration and anticipation of the often unpredictable consequences of science and technology (Owen, Macnaghten, and Stilgoe 2012). RRI lists six policy keys that RRI should advance: ethics, gender equality, governance, open access, public engagement, and science education (European Commission 2014). Perhaps a seventh, responsible quantification, should be added to the list.

8. Ethics of quantification, in principles

If one were to explain, after the illustration above, what an ethics of quantification consists of, one would be at loss to draw a synthesis in the present multiverse of numbers. In the field of statistics, in that of mathematical modelling, in those of algorithms and ratings, a multitude of aspirations, agendas, and interests are simultaneously at play. What can perhaps be suggested here are a few principles which could be usefully followed to move toward a more mature form of coexistence between number and society.

- The multidimensionality of the "algorithms of public relevance" (a definition due to (Gillespie 2014)) points a space of socio-political influence and public relevance of the quantification, requiring a balancing movement that the authors associate with an ethics of quantification. **An ethics of quantification as a framework to investigate the societal relevance of quantification.**
- Our analysis of the literature has focused on the cognitive dissonance between possibly adverse impact of quantification, and their purported function of universal certainty, neutrality, and control. **An ethics of quantification as vigilance about the spoken and unspoken framing and assumptions.**
- Quantification can belong to a culture of hubris or to one of humility (Jasanoff 2003). **An ethics of quantification as providing a compass to look at numbers along the humility-hubris axis.**

- The certainty of numbers and the neglect of ambiguity and ‘not-knowing’ (Gupta 2001) may limit the space of the possible policy solutions, or worse, it may offer to politics the chance to abdicate decision by transforming a political decision into a technical one, imposed by the certainty of the quantitative prediction. **An ethics of quantification for systematically probing for missing numbers and blind spots.**
- As mentioned in our perspective, both society and the collective of quantifiers have a useful role to play in a context of participation and activism. **An ethics of quantification as normative framework and intellectual home for various forms of data-, model- and stat-activism.**
- Quality of knowledge should be the primary tool helping to map main dimensions of social, political and economic phenomenon, overcoming knowledge asymmetries. Quality of knowledge can be assisted by a process of socially mediated quantification, with a role for forms of participative quality (van der Sluijs et al. 2005; Saltelli et al. 2013). **An ethics of quantification for fostering quality as fitness for societal purpose.**

These principles are not new, and can be found in different forms in different works concerned with e.g., mathematical modelling (Saltelli, Bammer, et al. 2020b), indicators (Engle Merry 2016), or algorithms (O’Neil 2016).

9. Conclusions

The present work has tried to emphasize commonalities among different families of quantification, to stress that these commonalities were not lost in the thought of the sociologists of numbers (Porter 1995), and that the call these scholars made yesterday for an ethics of quantification (Espeland and Stevens 2008) become all the more urgent today that societies live immersed in numbers, including those of COVIDS-19, which are both visible (number of deaths and infections) or invisible (social monitoring algorithms).

The magic power seduction of numbers (Engle Merry 2016) has increased enormously, including under the direction of platform and surveillance capitalism. As a result, form societal learning and coping have become at the same time more needed and more difficult.

The present perspective article tried to capture the common perspective that emerges from the authors’ reading of signals of concern from existing literature, and to derive from these readings

the good reasons why we as citizens and scholars should act now. An attempt has been made to show how asymmetries and lock ins stand in the way of a solution, especially since it is the model of political decision itself which has been subtracted from human agency and entrusted to the often-opaque logic of algorithms. Finally, a few reflections for policy have been offered, emphasizing the collective need and responsibility for actions, involving institutions, social actors, scholars and citizens.

COMPETING INTERESTS

The authors declare no competing interests.

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10. References

- Bastani, Aron. 2019. *Fully Automated Luxury Capitalism. A Manifesto*. New York: Verso.
- Beck, P U. 1992. *Risk Society: Towards a New Modernity*. Published in Association with Theory, Culture & Society. Sage Publications (CA).
- Begley, C G., and L. M Ellis. 2012. “Drug Development: Raise Standards for Preclinical Cancer Research.” *Nature* 483 (7391): 531–33. <http://dx.doi.org/10.1038/483531a>.
- Bella, Sam di. 2019. “Book Review: The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power by Shoshana Zuboff.” London School of Economics. 2019. <https://blogs.lse.ac.uk/lsereviewofbooks/2019/11/04/book-review-the-age-of-surveillance-capitalism-the-fight-for-the-future-at-the-new-frontier-of-power-by-shoshana-zuboff/>.
- Bradshaw, G. A., and Jeffrey G. Borchers. 2000. “Uncertainty as Information: Narrowing the Science-Policy Gap.” *Ecology and Society*. The Resilience Alliance. <https://doi.org/10.5751/es-00174-040107>.
- Bruno, I., E. Didier, and J. Prévieux. 2014. *Statactivisme. Comment Lutter Avec Des Nombres*. Paris: Zones, La Découverte.

- Bruno, Isabelle, Emmanuel Didier, and Tommaso Vitale. 2014. "Editorial: Statactivism: Forms of Action between Disclosure and Affirmation." *The Open Journal of Sociopolitical Studies* 2 (7): 198–220. <https://doi.org/10.1285/i20356609v7i2p198>.
- Cardiff University. 2020. "Data Justice Lab." School of Journalism, Media and Culture. 2020. <https://datajusticelab.org/>.
- Cath, Corinne, Sandra Wachter, Brent Mittelstadt, Mariarosaria Taddeo, and Luciano Floridi. 2018. "Artificial Intelligence and the 'Good Society': The US, EU, and UK Approach." *Science and Engineering Ethics* 24 (2): 505–28. <https://doi.org/10.1007/s11948-017-9901-7>.
- Chubin, Daryl E. 2001. "Filling the Policy Vacuum Created by OTA's Demise | Issues in Science and Technology." *Issues in Science and Technology* XVII (2). <https://issues.org/stalk-5/>.
- Collingridge, David. 1980. *The Social Control of Technology*. New York ;London: St. Martin's Press.
- Concialdi, Pierre. 2014. "Le BIP40: Alerte Sur La Pauvreté." In *Statactivisme. Comment Lutter Avec Des Nombres*, edited by I. Bruno, E. Didier, and J. Prévieux, 199–211. Zones, La Découverte.
- Copestake, Jen. 2019. "AI Ethics Backed by Pope and Tech Giants in New Plan." *BBC News*, February 2019. <https://www.bbc.com/news/technology-51673296>.
- Danaher, John, Michael ; Hogan, Chris; Noone, Ronan; Kennedy, Anthony ; Behan, Aisling; De Paor, Heike ; Flezmann, et al. 2017. "Algorithmic Governance: Developing a Research Agenda through the Power of Collective Intelligence." *Big Data and Society* 4 (2): 1–21.
- Didier, Emmanuel. 2020. "Politique Du Nombre de Morts." *AOC, Analyse Opinion Critique*, 2020. <https://aoc.media/opinion/2020/04/15/politique-du-nombre-de-morts/>.
- Drutman, Lee. 2015. *The Business of America Is Lobbying : How Corporations Became Politicized and Politics Became More Corporate*. Oxford University Press.
- Edwards, Marc A., and Siddhartha Roy. 2017. "Academic Research in the 21st Century: Maintaining Scientific Integrity in a Climate of Perverse Incentives and

Hypercompetition.” *Environmental Engineering Science* 34 (1): 51–61.

<https://doi.org/10.1089/ees.2016.0223>.

Engle Merry, Sally. 2016. *The Seductions of Quantification: Measuring Human Rights, Gender Violence, and Sex Trafficking*. University of Chicago Press.

<https://www.amazon.com/Seductions-Quantification-Measuring-Violence-Trafficking/dp/022626128X>.

Espeland, Wendy Nelson, and Mitchell L. Stevens. 2008. “A Sociology of Quantification.” *European Journal of Sociology* 49 (3): 401–36.

<https://doi.org/10.1017/S0003975609000150>.

European Commission. 2014. “Responsible Research and Innovation.” Science with and for Society Website. 2014.

https://ec.europa.eu/research/swafs/pdf/pub_rri/KI0214595ENC.pdf.

Fauci, Anthony. 2020. “There Is No Number-Answer.” Twitter. 2020.

<https://twitter.com/marioricciard18/status/1237778247011663872>.

Ferguson, Neil M., Derek A.T. Cummings, Christophe Fraser, James C. Cajka, Philip C. Cooley, and Donald S. Burke. 2006a. “Strategies for Mitigating an Influenza Pandemic - SUPPLEMENTARY INFORMATION.” *Nature*. https://static-content.springer.com/esm/art%3A10.1038%2Fnature04795/MediaObjects/41586_2006_BFnature04795_MOESM28_ESM.pdf.

———. 2006b. “Strategies for Mitigating an Influenza Pandemic.” *Nature* 442 (7101): 448–52. <https://doi.org/10.1038/nature04795>.

Ferguson, Neil M., Daniel Laydon, Gemma Nedjati-Gilani, Natsuko Imai, Kylie Ainslie, Zulma Cucunubá Marc Baguelin, Sangeeta Bhatia, Adhiratha Boonyasiri, Gina Cuomo-Dannenburg, et al. 2020. “Impact of Non-Pharmaceutical Interventions (NPIs) to Reduce COVID-19 Mortality and Healthcare Demand.” Imperial College London. 2020. <https://www.imperial.ac.uk/media/imperial-college/medicine/mrc-gida/2020-03-16-COVID19-Report-9.pdf>.

Foucault, M., G. Agamben, J.L. Nancy, R. Esposito, S. Benvenuto, D. Dwivedi, S. Mohan, R. Ronchi, and M. de Carolis. 2020. “Coronavirus and Philosophers.” *European Journal of Psychoanalysis*. 2020. <https://www.journal-psychoanalysis.eu/coronavirus-and->

philosophers/.

Frankel, Todd C. 2020. “The Government Has Spent Decades Studying What a Life Is Worth. It Hasn’t Made a Difference in the Covid-19 Crisis,” 2020.

<https://www.washingtonpost.com/business/2020/05/23/government-has-spent-decades-studying-what-life-is-worth-it-hasnt-made-difference-covid-19-crisis/>.

Fund, John. 2020. “Neil Ferguson’s Coronavirus Imperial College Model -- ‘Professor Lockdown’ Resigns in Disgrace.” *National Review*, May 6, 2020.

<https://www.nationalreview.com/corner/professor-lockdown-modeler-resigns-in-disgrace/>.

Funtowicz, Silvio, and Jerome R. Ravetz. 1993. “Science for the Post-Normal Age.” *Futures* 25 (7): 739–55. [https://doi.org/10.1016/0016-3287\(93\)90022-L](https://doi.org/10.1016/0016-3287(93)90022-L).

Gelman, Andrew. 2019. “‘Retire Statistical Significance’: The Discussion.” Blog: Statistical Modelling, Causal Inference and Social Sciences. 2019.

<https://statmodeling.stat.columbia.edu/2019/03/20/retire-statistical-significance-the-discussion/>.

Gigerenzer, G., and J. N. Marewski. 2014. “Surrogate Science: The Idol of a Universal Method for Scientific Inference.” *Journal of Management*, no. September: 0149206314547522-. <https://doi.org/10.1177/0149206314547522>.

Gillespie, T. 2014. “The Relevance of Algorithms.” In *Media Technologies: Essays on Communication, Materiality, and Society*, edited by P. J. Boczowski and K. A. Foot, 167–193. MIT press.

Goldacre, Ben. 2012. *Bad Pharma : How Drug Companies Mislead Doctors and Harm Patients*. Fourth Estate.

Gray, John. 2018. “Unenlightened Thinking: Steven Pinker’s Embarrassing New Book Is a Feeble Sermon for Rattled Liberals.” *New Statesman*, February 2018.

<https://www.newstatesman.com/culture/books/2018/02/unenlightened-thinking-steven-pinker-s-embarrassing-new-book-feeble-sermon>.

Gupta, S. 2001. “Avoiding Ambiguity: Scientist Sometimes Use Mathematics to Give the Illusion of Certainty.” *Nature* 412 (6847): 589. <https://doi.org/10.1038/35088152>.

- Harris, Richard F. 2017. *Rigor Mortis : How Sloppy Science Creates Worthless Cures, Crushes Hope, and Wastes Billions*. Basic Books.
- High-Level Expert Group on Artificial Intelligence. 2019. “Ethics Guidelines for Trustworthy AI.” European Commission Document. 2019. <https://ec.europa.eu/futurium/en/ai-alliance-consultation>.
- ILO. 2020. “COVID-19: Protecting Workers in the Workplace.” International Labour Organization. 2020. https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_745879/lang--en/index.htm.
- Introna, Lucas D. 2016. “Algorithms, Governance, and Governmentality.” *Science, Technology, & Human Values* 41 (1): 17–49. <https://doi.org/10.1177/0162243915587360>.
- Ioannidis, J. P. A. 2005. “Why Most Published Research Findings Are False.” *PLOS Medicine* 2 (8). <https://doi.org/10.1371/journal.pmed.0020124>.
- . 2016. “Evidence-Based Medicine Has Been Hijacked: A Report to David Sackett.” *Journal of Clinical Epidemiology* 73 (May): 82–86. <https://doi.org/10.1016/j.jclinepi.2016.02.012>.
- Jasanoff, Sheila. 2003. “Technologies of Humility: Citizen Participation in Governing Science.” *Minerva*. Springer. <https://doi.org/10.1023/A:1025557512320>.
- . 2007. “Technologies of Humility.” *Nature*. Nature Publishing Group. <https://doi.org/10.1038/450033a>.
- Kay, John A., and Mervyn A. King. 2020. *Radical Uncertainty : Decision-Making beyond the Numbers*. W. W. Norton & Company.
- Keiper, Adam. 2004. “Science and Congress.” *The New Atlantis*, 2004. <https://www.thenewatlantis.com/publications/science-and-congress>.
- Kitchin, Rob. 2017. “Thinking Critically about and Researching Algorithms.” *Information Communication and Society* 20 (1): 14–29. <https://doi.org/10.1080/1369118X.2016.1154087>.
- Kitching, R.P., M.V. Thrusfield, and N.M. Taylor. 2006. “Use and Abuse of Mathematical Models: An Illustration from the 2001 Foot and Mouthdisease Epidemic in the United

Kingdom.” *Scientific and Technical Review of the Office International Des Epizooties* 25 (1).

Landler, Mark, and Stephen Castle. 2020. “Behind the Virus Report That Jarred the U.S. and the U.K. to Action - The New York Times.” *The New York Times*, March 17, 2020. <https://www.nytimes.com/2020/03/17/world/europe/coronavirus-imperial-college-johnson.html>.

Lanier, J. 2006. *Who Owns the Future?* Penguin Books.

Law, Tara, and Gina Martinez. 2020. “A Timeline of Trump’s Hurricane Dorian, Alabama Controversy | Time.” *Time*, September 2020. <https://time.com/5671606/trump-hurricane-dorian-alabama/>.

Lazo, Jeffrey K., Rebecca E. Morss, and Julie L. Demuth. 2009. “300 Billion Served.” *Bulletin of the American Meteorological Society* 90 (6): 785–98. <https://doi.org/10.1175/2008BAMS2604.1>.

Lindeman, Mark, and Philip B. Stark. 2012. “A Gentle Introduction to Risk-Limiting Audits.” *IEEE Security & Privacy* 10 (5): 42–49. <https://doi.org/10.1109/MSP.2012.56>.

Linshi, Jack. 2015. “Germanwings Plane Crash: How Much Compensation for Victims’ Families? | Time.” *Time*, March 2015. <https://time.com/3763541/germanwings-plane-crash-settlement/>.

Luhmann, Niklas. 1995. *Social System*. Stanford University Press.

Macfarlane, Laurie. 2020. “By Protecting Rentier Interests, We Are Making the Most Vulnerable Pay for the Crisis.” *Open Democracy*, May 2020. <https://www.opendemocracy.net/en/oureconomy/protecting-rentier-interests-we-are-making-most-vulnerable-pay-crisis/>.

Mansley, L. M., A. I. Donaldson, M. V. Thrusfield, and N. Honhold. 2011. “Destructive Tension: Mathematics versus Experience - The Progress and Control of the 2001 Foot and Mouth Disease Epidemic in Great Britain.” *OIE Revue Scientifique et Technique* 30 (2): 483–98. <https://doi.org/10.20506/rst.30.2.2054>.

Matthews, D. 2018. “Can Technocracy Be Saved? An Interview with Cass Sunstein.” *Vox*, October 2018. <https://www.vox.com/future-perfect/2018/10/22/18001014/cass-sunstein->

cost-benefit-analysis-technocracy-liberalism.

Mirowski, Philip. 1991. *More Heat than Light : Economics as Social Physics, Physics as Nature's Economics*. Cambridge University Press.

———. 2011. *Science-Mart, Privatizing American Science*. Harvard University Press.

Moeller, H.G. 2006. *Luhmann Explained*. Open Court Publishing Company.

Muller, Jerry Z. 2018. *The Tyranny of Metrics*. Princeton University Press .

O'Neil, Cathy. 2016. *Weapons of Math Destruction : How Big Data Increases Inequality and Threatens Democracy*. Random House Publishing Group.

Owen, Richard, Phil Macnaghten, and Jack Stilgoe. 2012. "Responsible Research and Innovation: From Science in Society to Science for Society, with Society." *Science and Public Policy* 39 (6): 751–60. <https://doi.org/10.1093/scipol/scs093>.

Pielke, Jr, Roger A. 2007. *The Honest Broker*. Cambridge University Press.

Pielke, Roger Jr. 2020. "The Mudfight Over 'Wild-Ass' Covid Numbers Is Pathological." *Wired*, April 2020. <https://www.wired.com/story/the-mudfight-over-wild-ass-covid-numbers-is-pathological/>.

Pielke, Roger Jr., R. E. Carbone, Roger Pielke Jr., and R. E. Carbone. 2002. "WEATHER IMPACTS, FORECASTS, AND POLICY." *Bulletin of the American Meteorological Society* 83 (3): 293–403.

Pinker, Steven. 2018. *Enlightenment Now : The Case for Reason, Science, Humanism, and Progress*. Random House.

Popp Berman, E., and Daniel Hirschman. 2018. "The Sociology of Quantification: Where Are We Now?" *Contemporary Sociology* 47 (3): 257–66.

Porter, Theodore M. 1995. *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton University Press.
<https://books.google.es/books?id=oK0QpgVfIN0C>.

———. 2012. "Funny Numbers." *Culture Unbound* 4: 585–98.

Pueyo, Tomas. 2020. "Coronavirus: Why You Must Act Now." Medium. 2020.

<https://medium.com/@tomaspueyo/coronavirus-act-today-or-people-will-die-f4d3d9cd99ca>.

Ravetz, Jerome R. 1971. *Scientific Knowledge and Its Social Problems*. Oxford University Press.

Reinert, Erik S. 2000. "Full Circle: Economics from Scholasticism through Innovation and Back into Mathematical Scholasticism." *Journal of Economic Studies* 27 (4/5): 364–76. <https://doi.org/10.1108/01443580010341862>.

Rhodes, Tim, and Kari Lancaster. 2020. "Mathematical Models as Public Troubles in COVID-19 Infection Control: Following the Numbers." *Health Sociology Review*, May, 1–18. <https://doi.org/10.1080/14461242.2020.1764376>.

Rhodes, Tim, Kari Lancaster, and Marsha Rosengarten. 2020. "A Model Society: Maths, Models and Expertise in Viral Outbreaks." *Critical Public Health* 30 (3): 253–56. <https://doi.org/10.1080/09581596.2020.1748310>.

Salmon, F. 2009. "Recipe for Disaster: The Formula That Killed Wall Street." *Wired*, February 2009. <https://www.wired.com/2009/02/wp-quant/>.

Saltelli, Andrea. 2018. "Why Science's Crisis Should Not Become a Political Battling Ground." *Futures* 104: 85–90.

———. 2019. "Statistical versus Mathematical Modelling: A Short Comment." *Nature Communications* 10: 1–3. <https://doi.org/10.1038/s41467-019-11865-8>.

———. 2020. "Ethics of Quantification or Quantification of Ethics?" *Futures* 116. <https://doi.org/doi.org/10.1016/j.futures.2019.102509>.

Saltelli, Andrea, Ksenia Aleksankina, William Becker, Pamela Fennell, Federico Ferretti, Niels Holst, Sushan Li, and Qiongli Wu. 2019. "Why so Many Published Sensitivity Analyses Are False: A Systematic Review of Sensitivity Analysis Practices." *Environmental Modelling & Software* 114 (April): 29–39. <https://doi.org/10.1016/J.ENVSOF.2019.01.012>.

Saltelli, Andrea, and Paola Annoni. 2010. "How to Avoid a Perfunctory Sensitivity Analysis." *Environmental Modelling & Software* 25 (12): 1508–17. <https://doi.org/10.1016/j.envsoft.2010.04.012>.

- Saltelli, Andrea, Gabriele Bammer, Isabelle Bruno, Erica Charters, Monica Di Fiore, Emmanuel Didier, Wendy Nelson Espeland, et al. 2020a. "Five Ways to Make Models Serve Society: A Manifesto - Supplementary Online Material." *Nature* 582.
<https://www.nature.com/magazine-assets/d41586-020-01812-9/18121984>.
- . 2020b. "Five Ways to Ensure That Models Serve Society: A Manifesto." *Nature* 582: 482–84. <https://doi.org/10.1038/d41586-020-01812-9>.
- Saltelli, Andrea, Lorenzo Benini, Silvio Funtowicz, M. Giampietro, Matthias Kaiser, Erik S Reinert, and Jeroen P. van der Sluijs. 2020. "The Technique Is Never Neutral. How Methodological Choices Condition the Generation of Narratives for Sustainability." *Environmental Science and Policy* 106: 87–98.
- Saltelli, Andrea, and Paul-Marie Boulanger. 2019. "Technoscience, Policy and the New Media. Nexus or Vortex?" *Futures*, November, 102491.
<https://doi.org/10.1016/J.FUTURES.2019.102491>.
- Saltelli, Andrea, and Silvio Funtowicz. 2017. "What Is Science's Crisis Really about?" *Futures* 91: 5–11.
- Saltelli, Andrea, Ângela; Guimaraes Pereira, Jeroen P. van der Sluijs, and Silvio Funtowicz. 2013. "What Do I Make of Your Latinorumc Sensitivity Auditing of Mathematical Modelling." *International Journal of Foresight and Innovation Policy* 9 (2/3/4): 213–34.
<https://doi.org/10.1504/IJFIP.2013.058610>.
- Sareen, Siddharth, Kjetil Rommetveit, and Andrea Saltelli. 2020. "Ethics of Quantification: Illumination, Obfuscation and Performative Legitimation." *Palgrave Communications* Accepted.
- Sarewitz, D, R A Pielke, and R Byerly. 2000. *Prediction: Science, Decision Making, and the Future of Nature*. Island Press. <https://books.google.es/books?id=O0nxEU-deAUC>.
- Scheufele, Dietram A. 2014. "Science Communication as Political Communication." *Proceedings of the National Academy of Sciences of the United States of America* 111 Suppl (Supplement 4): 13585–92.
- Sluijs, Jeroen P. van der, Matthieu Craye, Silvio Funtowicz, Penny Kloprogge, Jerome R. Ravetz, and James Risbey. 2005. "Combining Quantitative and Qualitative Measures of

- Uncertainty in Model-Based Environmental Assessment: The NUSAP System.” *Risk Analysis* 25 (2): 481–92. <https://doi.org/10.1111/j.1539-6924.2005.00604.x>.
- Smaldino, P.E., and R. McElreath. 2016. “The Natural Selection of Bad Science.” *Royal Society Open Science* 3 (160384).
- Spencer, Keith A. 2020. “The Art of Scientific Deception: How Corporations Use ‘Mercenary Science’ to Evade Regulation.” *Salon.Com*, February 2020. <https://www.salon.com/2020/02/02/the-art-of-scientific-deception-how-corporations-use-mercenary-science-to-evade-regulation/>.
- Sridhar, Devi, and Maimuna S Majumder. 2020. “Modelling the Pandemic.” *BMJ* 369 (April): m1567. <https://doi.org/10.1136/bmj.m1567>.
- Steerpike. 2020. “Six Questions That Neil Ferguson Should Be Asked.” *The Spectator*, May 12, 2020. <https://www.spectator.co.uk/article/six-questions-that-neil-ferguson-should-be-asked>.
- Supiot, Alain. 2007. *Governance by Numbers: The Making of a Legal Model of Allegiance*. Oxford University Press.
- Taleb, Nassim Nicholas, and Yaneer Bar-Yam. 2020. “The UK’s Coronavirus Policy May Sound Scientific. It Isn’t.” *The Guardian*, March 25, 2020. <https://www.theguardian.com/commentisfree/2020/mar/25/uk-coronavirus-policy-scientific-dominic-cummings>.
- Thunstrom, Linda, Stephen Newbold, David Finnoff, Madison Ashworth, and Jason F. Shogren. 2020. “The Benefits and Costs of Flattening the Curve for COVID-19.” *SSRN Electronic Journal (to Appear in the Journal of Cost Benefit Analysis)*, March. <https://doi.org/10.2139/ssrn.3561934>.
- Viscusi, W. Kip. 2008. “The Flawed Hedonic Damages Measure of Compensation for Wrongful Death and Personal Injury.” *Journal of Forensic Economics* 20 (2): 113–35. <https://doi.org/10.5085/0898-5510-20.2.113>.
- Waltner-Toews, David, Annibale Biggeri, Bruna De Marchi, Silvio Funtowicz, Mario Giampietro, Martin O’Connor, Jerome R. Ravetz, Andrea Saltelli, and Jeroen P. van der Sluijs. 2020. “Post-Normal Pandemics: Why COVID-19 Requires a New Approach to

Science.” STEPS Centre Blog. 2020. <https://steps-centre.org/blog/postnormal-pandemics-why-covid-19-requires-a-new-approach-to-science/>.

Wilmott, P., and D. Orrell. 2017. *The Money Formula*. Wiley & Sons.

Wilsdon, James. 2016. *The Metric Tide : The Independent Review of the Role of Metrics in Research Assessment and Management*. Sage Publications, Ltd.
<https://uk.sagepub.com/en-gb/eur/the-metric-tide/book251812>.

Zuboff, Shoshana. 2019. *The Age of Surveillance Capitalism : The Fight for a Human Future at the New Frontier of Power*. PublicAffairs.

Zyphur, Michael J., and Dean C. Pierides. 2017. “Is Quantitative Research Ethical? Tools for Ethically Practicing, Evaluating, and Using Quantitative Research.” *Journal of Business Ethics* 143 (1): 1–16. <https://doi.org/10.1007/s10551-017-3549-8>.

ⁱ Most of the discussion is hosted on GitHub, and the relevant links are available at <https://bit.ly/2TknWR7>.