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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.

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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 non-additive (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 media[1] 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) and Kitching et al. (2006).

As noted, more realistically, by Anthony Fauci—a member of the White House Coronavirus Task Force at the time of this 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 this work in the journal Nature (Saltelli et al., 2020a). 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 et al., 2020a; 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 et al., 2020a).

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 mediatisation of science (Scheufele, 2014), its commodification (Mirowski, 2011) and politicisation (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/does not-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.

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 et al., 2020a, 2020b). 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 this 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 et al., 2009). From agriculture to transport to energy, virtually all sectors of the economy benefit from these models (Sarewitz et al., 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 et al., 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 et al., 2020a).

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 internalise challenges that arise outside their framing assumptions. All these remarks have been vindicated—in the opinion of the authors of this work—by the numbers populating the present pandemic (Saltelli et al., 2020a). 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 intellectuals 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 dematerialise, 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 later in the present work), 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).

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 colonised by numbers. Mathematical and statistical models, indicators, metrics and algorithms of various nature and complexity are used to maximise 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 et al., 2020a).
- 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 realisation 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 et al., 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.

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 optimises 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 mobilisation of the workers is total, in a homoeostatic 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-feudalisation of society.

A complementary reading of the situation is offered by the French movement of '*statactivistes*' (Bruno et al., 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* (Bruno et al., 2014; Bruno et al., 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). An International Research Network named "Society for the Social Studies of Quantification (SSSQ)" has been recently created, gathering scholars from disciplines such as history, philosophy, sociology, anthropology and political science (Didier, 2020b).

Other virtuous examples of data activism are described by O'Neil (O'Neil, 2016), pp. 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 et al., 2020b).

Reasons for an ethics of quantification

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

As noted above, 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 (Bruno et al., 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 et al., 2020a).
- 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 realising that "The technique is never neutral" (Saltelli 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 et al. (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 the Aadhaar system in India (Sareen et al., 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, 2020a; Foucault et al., 2020).

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. VSL are used in (Thunstrom et al., 2020) to assert 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.

Some emerging Implications for policy

What should be done?

Since the gist of this 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 reviews in (Cath et al., 2018), (Lo Piano, 2020) 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 et al., 2014), to the historians (Muller, 2018; Porter, 2012), and many others.

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

Role of organised 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 organised 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 lobbing 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 et al., 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.

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-activism, model-activism 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, 2019) (Saltelli et al., 2020a), indicators (Engle Merry, 2016), or algorithms (O'Neil, 2016).

Conclusions

This work has tried to emphasise 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, forms of 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,

emphasising the collective need and responsibility for actions, involving institutions, social actors, scholars and citizens.

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Note

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

References

Bastani A (2019) Fully automated luxury capitalism. A manifesto. Verso, New York
Beck PU (1992) Risk society: towards a new modernity. Published in Association with Theory, Culture and Society. Sage Publications, CA
Begley CG, Ellis LM (2012) Drug development: raise standards for preclinical cancer research. Nature 483(7391):531–533. https://doi.org/10.1038/483531a
Bella SD (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
Bradshaw GA, Borchers JG (2000) Uncertainty as information: narrowing the science-policy gap. Ecology and Society. The Resilience Alliance
Bruno I, Didier E, Prévieux J (2014) Statactivisme. Comment Lutter Avec Des Nombres. Zones, La Découverte, Paris
Bruno I, Didier E, Vitale T (2014) Editorial: statactivism: forms of action between disclosure and affirmation. Open J Sociopolit Stud 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 C, Wachter S, Mittelstadt B, Taddeo M, Floridi L (2018) Artificial intelligence and the 'good society': The US, EU, and UK Approach. Sci Eng Ethics 24 (2):505–528. https://doi.org/10.1007/s11948-017-9901-7
Chubin DE (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 D (1980) The social control of technology. St. Martin's Press, New York; London
Concialdi P (2014) Le BIP40: Alerte Sur La Pauvreté. In: Bruno I, Didier E, Prévieux J (eds) Statactivisme. Comment Lutter Avec Des Nombres. Zones, La Découverte. pp. 199–211
Copestake J (2019) AI Ethics Backed by Pope and Tech Giants in New Plan. BBC News Feb 2019. https://www.bbc.com/news/technology-51673296
Danaher J, Hogan M, Noone C, Kennedy R, Behan A, De Paor A, Flezmann H et al. (2017) Algorithmic governance: developing a research agenda through the power of collective intelligence. Big Data Soc 4(2):1–21
Didier E (2020a) Politique Du Nombre de Morts. AOC. Analyse Opinion Critique, 2020. https://aoc.media/opinion/2020/04/15/politique-du-nombre-de-morts/
Didier E (2020b) Society for the Social Studies of Quantification (SSSQ), https://en.ird.fr/project-sssq-society-social-studies-quantification
Drutman L (2015) The Business of America is lobbying: how corporations became politicized and politics became more corporate. Oxford University Press
Edwards MA, Roy S (2017) Academic research in the 21st century: maintaining scientific integrity in a climate of perverse incentives and hypercompetition. Environ Eng Sci 34(1):51–61. https://doi.org/10.1089/ees.2016.0223
Engle Merry S (2016) The seductions of quantification: measuring human rights, gender violence, and sex trafficking. University of Chicago Press
Espeland WN, Stevens ML (2008) A sociology of quantification. Eur J Sociol 49 (3):401–436. 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 A (2020) There is no number-answer. Twitter. https://twitter.com/marioricciard18/status/1237778247011663872
Ferguson NM, Cummings DAT, Fraser C, Cajka JC, Cooley PC, Burke DS (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
Ferguson NM, Cummings DAT, Fraser C, Cajka JC, Cooley PC, Burke DS (2006b) Strategies for mitigating an influenza pandemic. Nature 442(7101):448–452. https://doi.org/10.1038/nature04795
Ferguson NM, Laydon D, Nedjati-Gilani G, Imai N, Ainslie K, Baguelin ZCM, Bhatia S, Boonyasiri A, Cuomo-Dannenburg G, Dighe A (2020) Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. Imperial College, London
Foucault M, Agamben G, Nancy JL, Esposito R, Benvenuto S, Dwivedi D, Mohan S, Ronchi R, de Carolis M (2020) Coronavirus and Philosophers. Eur J Psychoanal, online issue: https://www.journal-psychoanalysis.eu/coronavirus-and-philosophers/
Frankel TC (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 J (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 S, Ravetz JR (1993) Science for the post-normal age. Futures 25 (7):739–55. https://doi.org/10.1016/0016-3287(93)90022-L
Gelman A (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, Marewski, JN (2014) Surrogate science: the idol of a universal method for scientific inference. J Manag 0149206314547522. https://doi.org/10.1177/0149206314547522
Gillespie T (2014) The relevance of algorithms. In Boczkowski PJ, Foot, KA (eds) Media Technologies: Essays on Communication, Materiality, and Society. MIT press, pp. 167–193
Goldacre B (2012) Bad pharma: how drug companies mislead doctors and harm patients. Fourth Estate
Gray J (2018) Unenlightened thinking: steven pinker's embarrassing new book is a feeble sermon for rattled liberals. New Stateman, Feb 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 RF (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 LD (2016) Algorithms, governance, and governmentality. Sci Technol Human Values 41(1):17–49. https://doi.org/10.1177/0162243915587360
Ioannidis JPA (2005) Why most published research findings are false. PLoS Med 2 (8). https://doi.org/10.1371/journal.pmed.0020124
Ioannidis JPA (2016) Evidence-based medicine has been hijacked: a report to David Sackett. J Clin Epidemiol 73(May):82–86. https://doi.org/10.1016/j.jclinepi.2016.02.012
Jasanoff S (2003) Technologies of humility: citizen participation in governing science. Springer, Minerva, 10.1023/A:1025557512320
Jasanoff S (2007) Technologies of humility. Nature. https://doi.org/10.1038/450033a
Kay JA, King MA (2020) Radical uncertainty: decision-making beyond the numbers. W. W. Norton & Company
Keiper A (2004) Science and congress. The New Atlantis, 2004. https://www.thenewatlantis.com/publications/science-and-congress
Kitchin R (2017) Thinking critically about and researching algorithms. Inform Commun Soc 20(1):14–29. https://doi.org/10.1080/1369118X.2016.1154087
Kitching RP, Thrusfield MV, Taylor NM (2006) Use and abuse of mathematical models: an illustration from the 2001 foot and mouthdisease epidemic in the United Kingdom. Sci Tech Rev Office Int Des Epizooties 25 (1):293
Landler M, Castle S (2020) Behind the virus report that jarred the U.S. and the U.K. to action. 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 T, Martinez G (2020) A Timeline of Trump's Hurricane Dorian, Alabama Controversy|Time. Time, September 2020. https://time.com/5671606/trump-hurricane-dorian-alabama/
Lazo JK, Morss RE, Demuth JL (2009) 300 billion served. Bull Am Meteorol Soc 90 (6):785–98. https://doi.org/10.1175/2008BAMS2604.1
Lindeman M, Stark PB (2012) A gentle introduction to risk-limiting audits. IEEE Security Privacy 10(5):42–49. https://doi.org/10.1109/MSP.2012.56
Linshi J (2015) Germanwings plane crash: how much compensation for victims' families?|Time. Time, March 2015. https://time.com/3763541/germanwings-plane-crash-settlement/
Lo Piano S (2020) Ethical principles in machine learning and artificial intelligence: cases from the field and possible ways forward. Humanities and Social Sciences Communications 7(1)

Luhmann N (1995) Social system. Stanford University Press
Macfarlane L (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 LM, Donaldson AI, Thrusfield MV, Honhold N (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):483–498. 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 P (1991) More heat than light: economics as social physics, physics as nature's economics. Cambridge University Press
Mirowski P (2011) Science-mart, privatizing American science. Harvard University Press
Moeller HG (2006) Luhmann explained. Open Court Publishing Company
Muller JZ (2018) The tyranny of metrics. Princeton University Press
O'Neil C (2016) Weapons of math destruction: how big data increases inequality and threatens democracy. Random House Publishing Group
Owen R, Macnaghten P, Stilgoe J (2012) Responsible research and innovation: from science in society to science for society, with society. Sci Public Policy 39 (6):751–760. https://doi.org/10.1093/scipol/scs093
Pielke RA Jr (2007) The honest broker. Cambridge University Press
Pielke R 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 Jr R, Carbone RE, Pielke Jr R, Carbone RE (2002) Weather impacts, forecasts, and policy. Bull Am Meteorol Soc 83(3):293–403
Pinker S (2018) Enlightenment now: the case for reason, science, humanism, and progress. Random House
Popp Berman E, Hirschman D (2018) The sociology of quantification: where are we now? Contemporary Sociol 47(3):257–266
Porter TM (1995) Trust in numbers: the pursuit of objectivity in science and public life. Princeton University Press
Porter TM (2012) Funny numbers. Cult Unbound 4:585–598
Pueyo T (2020) Coronavirus: why you must act now. Medium. 2020. https://medium.com/@tomaspueyo/coronavirus-act-today-or-people-will-die-f4d3d9cd99ca
Ravetz JR (1971) Scientific knowledge and its social problems. Oxford University Press
Reinert ES (2000) Full circle: economics from scholasticism through innovation and back into mathematical scholasticism. J Econ Stud 27(4/5):364–376. https://doi.org/10.1108/01443580010341862
Rhodes T, Lancaster K (2020) Mathematical models as public troubles in COVID-19 infection control: following the numbers. Health Sociol Rev 1–18. https://doi.org/10.1080/14461242.2020.1764376
Rhodes T, Lancaster K, Rosengarten M (2020) A model society: maths, models and expertise in viral outbreaks. Crit Public Health 30(3):253–256. https://doi.org/10.1080/09581596.2020.1748310
Salmon F (2009) Recipe for disaster: the formula that killed wall street. Wired, Feb 2009. https://www.wired.com/2009/02/wp-quant/
Saltelli A (2018) Why science's crisis should not become a political battling ground. Futures 104:85–90
Saltelli A (2019) Statistical versus mathematical modelling: a short comment. Nat Commun 10:1–3. https://doi.org/10.1038/s41467-019-11865-8
Saltelli A (2020) Ethics of quantification or quantification of ethics? Futures 116. https://doi.org/10.1016/j.futures.2019.102509
Saltelli A, Annoni P (2010) How to avoid a perfunctory sensitivity analysis. Environ Model Software 25(12):1508–1517. https://doi.org/10.1016/j.envsoft.2010.04.012
Saltelli A, Aleksankina K, Becker W, Fennell P, Ferretti F, Holst N, Li S, Wu Q (2019) Why so many published sensitivity analyses are false: a systematic review of sensitivity analysis practices. Environ Model Software 114 (April):29–39. https://doi.org/10.1016/J.ENVSOFT.2019.01.012
Saltelli A, Bammer G, Bruno I, Charters E, Di Fiore M, Didier E, Espeland WN et al. (2020a) Five ways to ensure that models serve society: a manifesto. Nature 582:482–484. https://doi.org/10.1038/d41586-020-01812-9
Saltelli A, Bammer G, Bruno I, Charters E, Di Fiore M, Didier E, Espeland WN, Kay J, Piano SL, Mayo D, Pielke Jr R (2020b) 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
Saltelli A, Benini L, Funtowicz S, Giampietro M, Kaiser M, Reinert ES, van der Sluijs JP (2020) The technique is never neutral. how methodological choices condition the generation of narratives for sustainability. Environ Sci Policy 106:87–98
Saltelli A, Boulanger P-M (2019) Technoscience, policy and the new media. nexus or vortex? Futures, Nov 102491. https://doi.org/10.1016/J.FUTURES.2019.102491
Saltelli A, Funtowicz S (2017) What is science's crisis really about? Futures 91:5–11
Saltelli A, Pereira ÂG, van der Sluijs JP, Funtowicz S (2013) What do i make of your latinorumc sensitivity auditing of mathematical modelling. Int J Foresight Innovat Policy 9(2/3/4): 213–234. https://doi.org/10.1504/IJFIP.2013.058610
Sareen S, Rommetveit K, Saltelli A (2020) Ethics of quantification: illumination, obfuscation and performative legitimation. Pal Commun 6:1–5
Sarewitz D, Pielke RA, Byerly R (2000) Prediction: science, decision making, and the future of nature. Island Press
Scheufele DA (2014) Science communication as political communication. Proc Natl Acad Sci USA 111 Suppl (Supplement 4): 13585–13592
Smaldino PE, McElreath R (2016) The natural selection of bad science. Royal Soc Open Sci 3:160384
Spencer KA (2020) The art of scientific deception: how corporations use 'mercenary science' to evade regulation. *Salon.Com*, Feb 2020. https://www.salon.com/2020/02/02/the-art-of-scientific-deception-how-corporations-use-mercenary-science-to-evade-regulation/
Sridhar D, Majumder MS (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 A (2007) Governance by numbers: the making of a legal model of allegiance. Oxford University Press
Taleb NN, Bar-Yam Y (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 L, Newbold S, Finnoff D, Ashworth M, Shogren JF (2020) The Benefits and Costs of Flattening the Curve for COVID-19. SSRN Electron J https://doi.org/10.2139/ssrn.3561934
van der Sluijs JP, Craye M, Funtowicz S, Kloprogge P, Ravetz JR, Risbey J (2005) combining quantitative and qualitative measures of uncertainty in model-based environmental assessment: the NUSAP system. Risk Anal 25 (2):481–942. https://doi.org/10.1111/j.1539-6924.2005.00604.x
Viscusi WK (2008) The flawed hedonic damages measure of compensation for wrongful death and personal injury. J Forensic Econ 20(2):113–135. https://doi.org/10.5085/0898-5510-20.2.113
Waltner-Toews D, Biggeri A, Marchi B De, Funtowicz S, Giampietro M, O'Connor M, Ravetz J R, Saltelli A, van der Sluijs JP (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, Orrell D (2017) The money formula. Wiley & Sons
Wilsdon J (2016) The metric tide: the independent review of the role of metrics in research assessment and management. Sage Publications, Ltd
Zuboff S (2019) The age of surveillance capitalism: the fight for a human future at the new frontier of power. PublicAffairs
Zyphur MJ, Pierides DC (2017) Is quantitative research ethical? tools for ethically practicing, evaluating, and using quantitative research. J Business Ethics 143(1):1–16. https://doi.org/10.1007/s10551-017-3549-8

Competing interests

The authors declare no competing interests.

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