Endeavour 43 (2019) 100709

Contents lists available at ScienceDirect

Endeavour

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

Ethical control of innovation in a globalized and liberal world: Is good science still science?

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ARTICLE INFO

Article history:
Available online 27 February 2020

Keywords:
Innovation
Global threat
Business ethics
Corporate social responsibility
Science ethics
Liberalism
Mertonian norms
Good science
One health concept

ABSTRACT

The independence of science was long seen as of prime importance. This position has become less common today. The perception of scientific research as a public service has led to the opinion that it must be accountable to citizens and produce knowledge and innovation that meet their expectations. Numerous authors have voiced the need for anticipatory ethical control of innovation focusing on the scientific research process. This control is considered as the must-have guarantee for "good science." The current article attempts to trace the ideological origins of the ethical control of innovation, examines its effectiveness against the challenge of globalization and technology-derived major threats and its compatibility with scientific methodology. It also suggests ways to both regulate the innovation process and preserve the independence of science. On the whole, we conclude that truly effective ethical regulation of innovation, i.e. one that protects the greatest number from its adverse effects, is achieved first and foremost by questioning our liberal economic model and the place given to science in our societies.

Responsible research and innovation

The organisation for Economic Co-operation and Development (OECD) defines innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations."[1] Since the pioneering work of Schumpeter, most modern economic theories consider that a high frequency of technological innovation favors economic growth.[2] In addition, innovation in the field of life sciences has been closely associated with better quality and longer life, leading governments worldwide and the OECD to call for greater investment in this area.[3] There have also been attempts at changing legislation so that innovation can take place more freely. However, innovation has also long been known to also have possible detrimental effects.

From a theoretical point of view, Schumpeter's creative-destruction concept of innovation states that innovation can lead to disruptive and costly changes in an economic organization that render certain modes of production obsolete.[4] Innovation can also directly or indirectly induce positive or negatives effects via complex interactions in domains very far removed from their scope, which means that these effects are largely unpredictable. Moreover, research processes leading to innovation can raise ethical issues such as the use of animals in experiments or the respect of private data of participants in clinical trials.[5] Thus, numerous authors have claimed that there is an urgent need to build an ethics of scientific research that provides a moral and sociopolitical framework for thinking about the values, goals,

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[1] Organisation for Economic Co-operation and Development (OECD) and Eurostat, *Oslo Manual Guidelines for Collecting and Interpreting Innovation Data* (Paris: OECD, 2005), 46, https://doi.org/10.1787/9789264013100-en.

[2] Joseph Schumpeter, *The Theory of Economic Development, An Inquiry into Profits, Capital, Credit, Interest, and the Business* (Cambridge, MA: Harvard University Press, 1934); Sefer Şener and Ercan Saridoğan, "The Effects of Science-Technology-Innovation on Competitiveness and Economic Growth," *Procedia—Social and Behavioral Sciences.* no. 24 (2011): 815–28, https://doi.org/10.1016/j.sbspro.2011.09.127; Andreea Maria Pece, Olivera Ecaterina Oros Simona, and Florina Salisteanu, "Innovation and Economic Growth: An Empirical Analysis for CEE Countries," *Procedia Economics and Finance* 26, no. 15 (2015): 461–67, https://doi.org/10.1016/S2212-5671(15)00874-6.

[3] Frank R. Lichtenberg, "The Impact of Biomedical Innovation on Longevity and Health," *Nordic Journal of Health Economics* 5, no. 1 (2017): 45–57; Dominique Guellec and Sacha (Oecd) Wunsch-Vincent, "Policy Responses to the Economic Crisis: Investing in Innovation for Long-Term Growth," *OCDE*, no. 159 (2009): 1–37.

[4] Schumpeter, *The Theory of Economic Development* (ref. 2).

[5] Dominik Gross and René H. Tolba, "Ethics in Animal-Based Research," *European Surgical Research* 55, no. 1–2 (2015): 43–57, https://doi.org/10.1159/000377721; Deven McGraw, *et al.*, "Privacy and Confidentiality in Pragmatic Clinical Trials," *Clinical Trials* 12, no. 5 (2015): 520–29, https://doi.org/10.1177/1740774515597677.

http://dx.doi.org/10.1016/j.endeavour.2020.100709

processes and outcomes of innovation as an object of scrutiny.[6] The concept of "Responsible Research and Innovation" (RRI) has garnered much attention. Multiple definitions have been proposed and are cited as criteria for funding research.[7] Stahl defines RRI as "a higher-level responsibility or meta-responsibility that aims to shape, maintain, develop, coordinate and align existing and novel research and innovation-related processes, actors and responsibilities with a view to ensuring desirable and acceptable research outcomes."[8]

The challenges of an innovation ethic in a globalized and liberal world

The ethical control of innovation requires not only anticipating its societal impacts, which is already a perilous task due to the complexity and unpredictability of innovation, but also estimating the ethical value of those impacts. Traditionally this was done with reference to ethical norms that depend on concepts such as right and wrong or justice and crime and set standards, which define acceptable and unacceptable behavior in society. Ethical norms have complex religious, philosophical and cultural origins. This article argues that this traditional conception of ethics is challenged by the emergence of a globalized world and technology-derived major threats as well as by philosophical and liberal economic ideology.

Through the development of communication and transport technologies, the twentieth century saw exponential growth in the interconnection of individuals, economies and states, leading to a so-called "globalized world" where innovation spreads at lightning speed. Technological or organizational innovations rarely remain confined to one country. Consequently, the regulation of innovation must be conceived at the global level and implicate populations adhering to various religions and cultures with different, and sometimes incompatible, ethical norms. In recent decades, Muslim, Catholic, and Amish scholars have proposed ethical frameworks compatible with their beliefs to frame technological innovation.[9] In the same way, theoreticians of the genre have conceptualized technology as both a source and consequence of gender relations, leading to the idea that a feminist ethic of innovation is thus key to achieving gender equality.[10] Proponents of the vegan movement have attempted to introduce vegan moral concepts, such as banishing animal exploitation and consumption of animal products, within the ethical norms used to judge the interest of new technological developments. These examples suggest that the diversity of ethical norms can lead to a very different perception of the societal interests of innovation, making a consensual ethical regulation of innovation highly problematic. As we will discuss later in this article, globalization has also made many technology-derived threats a global concern regardless of their ability to disseminate. Some technologies, even when produced and used locally, can have a global effect, for example by modifying the climate or the availability of natural resources, and thus strongly affect populations that did not even choose to use those same technologies. This further reinforces the need for global control of innovation. Thus, in many ways, globalization has modified the conditions and stakes of the ethical control of innovation. To be efficient, innovation can no longer be seen solely as local and subject to religious or cultural norms. It must be global and based on universal knowledge able to convince most individuals.

Our modern societies are dominated by liberal ideology. What is the impact of the ideas conveyed by liberalism on the ethical control of innovation? Political liberalism tends to privatize religious practices and morality, which in practice leads to the abandonment of rigid ethical norms and their replacement with an ethical consensus produced by consultation between the various stakeholders. This process is considered democratic and very similar to the free market since it is based on the free competition of opinions. Moreover, economic liberalism promotes the maintenance of a state of exacerbated competition between the main players in technological innovation: universities and private companies. As many examples demonstrate, this competitive climate has led to many abuses and often tends to favor the predominance of private interests over the general good. These effects of liberalism will be described and discussed in greater detail later in this article.

Presently, ethical control focuses mainly on academic research funding stage. This funding depends on recognition of the societal and economic interest of research projects.[11] As the potential societal and economic interests presented in research project proposals are often mere statements of intent and do not lend themselves to a realistic assessment of their impacts, several authors have proposed that academic researchers and ethicists should meet regularly to continuously engage researchers on the social and ethical aspects of their work, a process termed "midstream level modulation."[12] However, scientific knowledge can be considered as a common good and a source of many societal benefits. It is even indispensable to determine the effects of innovation and inform governments and the public of danger. From this point of view, if ethical control aims to protect the general good, ethicists must also consider the potential impact of this growing ethical control over the methodology of basic scientific research.

As this introduction suggests, the stakes of the ethical control of innovation in a globalized world are extremely high, and the issue is highly complex. Such ethical control involves actors in fields of knowledge that are far removed from each other, such as philosophy, science, economy and governance. This article therefore uses a "system-based approach" to analyse this complex issue. This approach, introduced in the 1950s, has been used in various domains such as psychology, engineering and biology to

6 Wendy Lipworth and Renata Axler, "Towards a Bioethics of Innovation," *Journal of Medical Ethics* 42, no. 7 (2016): 445–49, https://doi.org/10.1136/medethics-2015-103048; Jack Stilgoe, Richard Owen, and Phil Macnaghten, "Developing a Framework for Responsible Innovation," *Research Policy* 42, no. 9 (2013): 1568–80, https://doi.org/10.1016/j.respol.2013.05.008.

7 Bernd Carsten Stahl, "Responsible Research and Innovation: The Role of Privacy in an Emerging Framework," *Science and Public Policy* 40, no. 6 (2013): 708–16,. https://doi.org/10.1093/scipol/sct067; R. von Schomberg, "A Vision of Responsible Innovation," in *Responsible Innovation*. Managing the Responsible Emergence of Science and Innovation in Society, ed. Richard Owen, John R. Bessant and Maggy Heintz (Chichester: Wiley, 2013), 51–74, https://doi.org/10.1002/9781118551424.ch3; Michael Davis and Kelly Laas, "'Broader Impacts' or 'Responsible Research and Innovation'? A Comparison of Two Criteria for Funding Research in Science and Engineering," *Sci Eng Ethics* 20, no. 4 (2014): 963–83, https://doi.org/10.1007/s11948-013-9480-1.

8 Bernd Carsten Stahl, "Responsible Research and Innovation: The Role of Privacy in an Emerging Framework," *Science and Public Policy* 40, no. 6 (2013): 708–16, on 708.

9 Amana Raquib, "The Islamic Standard for the Assessment of Modern Technology," *Revelation and Science* 3, no. 2 (2013): 1–8; Brian Green, "The Catholic Church and Technological Progress: Past, Present, and Future," *Religions* 8, no. 6 (2017): 106, https://doi.org/10.3390/rel8060106; Lindsay Ems, "Amish Workarounds: Toward a Dynamic, Contextualized View of Technology Use," *Journal of Amish and Plain Anabaptist Studies* 2, no. 1 (2014): 42–58.

10 Judy Wajcman, "Feminist Theories of Technology," *Cambridge Journal of Economics* 34, no. 1 (2010): 143–52, https://doi.org/10.1093/cje/ben057.

11 Erik Ernø-Kjølhede and Finn Hansson, "Measuring Research Performance during a Changing Relationship between Science and Society," *Research Evaluation* 20, no. 2 (2011): 131–43, https://doi.org/10.3152/095820211X12941371876544.

12 Erik Fisher, Roop L. Mahajan, and Carl Mitcham, "Midstream Modulation of Technology: Governance From Within," *Bulletin of Science, Technology & Society* 26, no. 6 (2006): 485–96, https://doi.org/10.1177/0270467606295402; Daan Schuurbiers, "What Happens in the Lab: Applying Midstream Modulation to Enhance Critical Reflection in the Laboratory," *Science and Engineering Ethics* 17, no. 4 (2011): 769–88, https://doi.org/10.1007/s11948-011-9317-8; Philip A. E. Brey, "Anticipatory Ethics for Emerging Technologies," *NanoEthics* 6, no. 1 (2012): 1–13, https://doi.org/10.1007/s11569-012-0141-7.

consider the interactions between the agents of the entire system to achieve the task of the system.[13] We can postulate that the aim of the ethical regulation of innovation in a globalized world should ideally be to preserve the interests of as many people as possible. In this article I will therefore first try to highlight the interconnections between the main agents of innovation, such as universities, private enterprises, scientific methodology, and the influence of the ideas associated with liberal ideology and try to analyze the resulting dynamics. I will then try to determine whether the current ethical control system successfully guarantees the general good and preserves the effectiveness of scientific methodology.

This article is organized in four parts. I first examine the stakes and conditions of ethical control in a globalized and liberal world. Then I describe what the ethical control of innovation currently consists of. Next I discuss whether the current control system is compatible with scientific methodology. Lastly, in the final section, I propose ways to achieve more effective ethical regulation of innovation while preserving the independence of science and not affecting the effectiveness of its methodology.

Globalization and modern technologies favor the emergence of unprecedented global threats and challenge traditional ethics

Humankind has survived countless wars, disease pandemics and natural disasters throughout the ages. But today our civilization faces unprecedented global threats, such as nuclear war, chemical pollution and climate change. Interestingly, all of these challenges take root in modern technological innovations.[14] A recent study evaluated the probability of human extinction.[15] Unsurprisingly, the authors concluded that the risks of anthropogenic extinction linked to technologies are likely greater than natural ones such as asteroid impacts, super-volcanic eruptions and epidemic diseases. We will briefly review three examples of major global technology threats to identify the characteristics they share in light of the issue of the ethical control of innovation.

The first atomic bomb was detonated in a test in the New Mexico desert in July 1945. The two next atomic bombs were dropped soon thereafter on Hiroshima and Nagasaki, killing instantly approximately 200,000 people. At the beginning of the twenty-first century, there are about 27,000 nuclear warheads, of which 12,000 are operational and 5000 on high alert status, ready for “launch on warning” in fifteen minutes.[16] That these nuclear weapons would be kept for eternity and never used, accidentally or intentionally, defies common sense. In 1962, during the Cuban missile crisis, the president of the United States, John F. Kennedy, put the odds of nuclear war at “somewhere between one out of three and even.” Moreover, the acquisition of nuclear weapons by new countries that do not necessarily have technologies to secure them has only increased the threat.[17] It is impossible to protect populations against such weapons. Thus, the only effective preventive measure to abolish nuclear weapons entirely. This rational measure is not on the agenda of governments with nuclear weapons. As recently demonstrated by the fact that the United States and Russia withdrew from the 1987 intermediate-range nuclear forces treaty in 2019. The argument most often put forward is that the existence of nuclear weapons has become indispensable for the maintenance of peace, though this has not been convincing for the board of directors of the Bulletin of the Atomic Scientists, including fifteen Nobel laureates, which advanced its Doomsday Clock to two minutes until Armageddon in 2018.

Since they were invented in the 1930s, chlorofluorocarbons (CFCs) have been considered as one of most successful products. They offered clear-cut advantages over other earlier alternatives used in refrigeration because they were nontoxic and relatively inexpensive to produce.[18] But, in the early 1970s, scientists discovered that CFCs persist in the atmosphere and their derivatives, free chlorine atoms, cause a significant reduction in the stratospheric ozone layer that protects us from ultraviolet irradiation.[19] In 1985, British scientists discovered the Antarctic ozone hole and predicted a gradual decline in stratospheric ozone levels over the long term.[20] This led to the 1987 Montreal protocol which totally banned all CFCs and to the establishment of a multilateral fund to provide financial assistance to help developing countries abandon the use of CFCs. The Montreal Protocol is viewed as a success story of international environmental policy and business ethic. However, because the destruction of CFCs in the stratosphere is a slow process, the threat of detrimental exposure to ultraviolet radiation still persists today. In addition, recent studies have revealed that emissions of CFCs are rising again, presumably in Asia, despite international rules restricting their use. Moreover, levels of other gasses, such as dichloromethane, not controlled by the Montreal Protocol have been increasing rapidly and also affect the ozone layer.[21]

During the twentieth century, the improvement of agricultural techniques, and especially the growing use of chemical fertilizers and pesticides, has produced a sharp increase in agricultural productivity.[22] This combined with better control of epidemics, thanks to vaccination, antibiotics and hygiene, led to a tripling of the world’s human population in just 50 years. However, these new agricultural practices and the subsequent demographic explosion caused widespread destruction of ecosystems and contributed to major climate change and a new era of mass extinction of species associated with human activity, called the Anthropocene.[23] Agriculture today is a major driver of environmental degradation.[24] Regions of dense settlement and intensive agriculture are correlated to poor water quality, and this affects both human water

[13] Ivan V. Maly, “Introduction: A Practical Guide to the Systems Approach in Biology,” *Systems Biology* 500 (2009): 3–13, https://doi.org/10.1007/978-94-007-6803-1.

[14] Robert Allen Schultz, “Modern Technology and Human Extinction,” *Proceedings of the 2016 InSITE Conference*, 2016, 131–45, https://doi.org/10.28945/3433.

[15] Andrew E. Snyder-Beattie, Toby Ord, and Michael B. Bonsall, “An Upper Bound for the Background Rate of Human Extinction,” *Scientific Reports* 9, no. 1 (2019): 11054, https://doi.org/10.1038/s41598-019-47540-7.

[16] Ronald McCoy, “The Continuing Risk of Nuclear War.,” *Medicine, Conflict, and Survival* 23, no. 4 (2007): 259–66, https://doi.org/10.1080/13623690701596668.

[17] Geoff Brumfiel, “Nuclear War: The Safety Paradox,” *Nature* 451, no. 7176 (2008): 230–31, https://doi.org/10.1038/451230a.

[18] “There’s Money in the Air: The CFC Ban and Dupont’s Regulatory Strategy,” *Business Strategy and the Environment* 6, no. 5 (1997): 276–86, https://doi.org/10.1002/(SICI)1099-0836(199711)6:5<276::AID-BSE123>3.0.CO;2-A.

[19] M. J. Milina and F. S. Rowland, “Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom-Catalysed Destruction of Ozone,” *Nature* 249 (1974): 810–12.

[20] J. C. Farman, B. G. Gardiner, and J. D. Shanklin, “Large Losses of Total Ozone in Antarctica Reveal Seasonal ClOx/NOx Interaction,” *Nature* 315 (1985): 207–10, https://doi.org/10.1038/313579a0.

[21] Stephen A Montzka, *et al.*, “An Unexpected and Persistent Increase in Global Emissions of Ozone-Depleting CFC-11,” *Nature* 557, no. 7705 (2018): 413–17; M. Rigby, *et al.*, “Increase in CFC-11 Emissions from Eastern China Based on Atmospheric Observations,” *Nature* 569, no. 7757 (2019): 546–50, https://doi.org/10.1038/s41586-019-1193-4; Ryan Hossaini, *et al.*, “The Increasing Threat to Stratospheric Ozone from Dichloromethane,” *Nature Communications* 8, no. May (2017): 1–9, https://doi.org/10.1038/ncomms15962.

[22] Wasim Aktar, Dwaipayan Sengupta, and Ashim Chowdhury, “Impact of Pesticides Use in Agriculture: Their Benefits and Hazards,” *Interdisciplinary Toxicology* 2, no. 1 (2009): 1–12, https://doi.org/10.2478/v10102-009-0001-7; Jonathan A. Foley, *et al.*, “Solutions for a Cultivated Planet,” *Nature* 478, no. 7369 (2011): 337–42, https://doi.org/10.1038/nature10452.

[23] Simon L. Lewis and Mark A. Maslin, “Defining the Anthropocene,” *Nature* 519, no. 7542 (2015): 171–80, https://doi.org/10.1038/nature14258.

[24] Jonathan A. Foley, *et al.*, “Global Consequences of Land Use,” *Science* 309, no. 5734 (2005): 570–74, https://doi.org/10.1126/science.1111772; Foley, *et al.*, “Solutions for a Cultivated Planet” (ref. 22).

security and freshwater and marine biodiversity.[25] Agriculture is also responsible for about 22 % of global anthropogenic greenhouse gas (GHG) emissions and thus is a major contributor to climate change.[26] Though pesticides have increased food production and contribute to fighting vector-borne diseases, their massive use has resulted in serious human health implications and unwanted side effects for the environment.[27]

These examples highlight several characteristics of technology-derived threats that must be considered in order to efficiently regulate technological innovations. With the notable exception of atomic weapons, it must be emphasized that it is almost impossible to predict the cascade of all positive and negative long-term effects of an innovation. An emerging technology integrates into a highly complex and growing network of existing technologies that interact positively or negatively with each other. A technology can also modify the environment and thus affect the gains or damages caused by itself or another technology differently over time. The complexity of the technological network makes it deeply non-deterministic. Thus, even upon retrospective analysis, it is often difficult to establish the causal link between scientific discoveries, innovation and their multiple societal effects.[28] Although used locally, some technologies can have a great and persistent impact at the global level and thus affect future generations. In addition, they can be highly addictive by changing our living conditions and our environment in such a way that we become totally dependent on them.

This leads us to several simple but fundamental conclusions:

- By their ability to rapidly disseminate and affect all individuals, even if acting only locally, innovations should be evaluated in the perspective of the general good.
- Some global threats related to technology may potentially lead to the rapid extinction of the human species, which makes the ethical control of innovations a top priority.
- Scientific uncertainty characterizes most threats related to technology. It is unreasonable to hope to be able to predict and especially to quantify all the positive or negative societal effects of an innovation, as some propose to do. And it is likewise just as unreasonable to expect scientific certainty to act.
- Multidisciplinary scientific knowledge often appears indispensable to simply establish the causality between an undesirable phenomenon and the use of a technology.
- To be effective, a control of technological innovation should be global and, because some technologies can be addictive, should be implemented before the innovation is introduced or shortly thereafter.

Liberal philosophy favors the privatization of ethical norms and considers that a free market guarantees the general good

As discussed previously, globalization strongly favors the dissemination of innovations which leads to a change in the quality of life of a growing number of people, regardless of their religion, culture and of the acceptance/rejection of these innovations. Therefore, one fundamental goal of a modern ethic that considers the phenomenon of globalization should be to identify what constitutes the general good. This step is essential to then determine whether an innovation has a reasonable probability of negatively affecting it. How does liberal ideology, which dominates both the social and economic structure of our societies, define the general good and in what way is it thought to guarantee it?

To answer this question, we first need a brief introduction to liberalism. It is important to note that liberalism is presently the subject of many and often violent controversies that result from disagreement over the very meaning of the term depending on whether it is used in philosophy, politics or economics. To avoid any misunderstanding, we will present some very basic ideas that are generally associated with liberalism. When we use the term liberalism, it will be in reference to these ideas.

Historically, the liberal doctrine has its roots in the Enlightenment philosophical movement and the opposition to religious dogmatism and monarchical absolutism. It builds on the importance of individual freedom, especially freedom of expression, ownership and commerce. It postulates that the freedom of individuals must be limited only by the need to protect the freedom of others and advocates the union and pacification of society through the privatization of religion, perceived as a source of division and war.

Liberalism is characterized by a mechanical vision of the organization of society. Free market mechanisms are purported to guarantee the general good in the form of unlimited economic growth. And legal mechanisms replace religious or philosophical morals to regulate the interactions between individuals. As proposed by the philosopher and economist Adam Smith, whose works constitute the conceptual basis for economic liberalism, selfishness and the defense of private interests are the engine of economic growth and the source of common good.[29] This is exemplified by the famous maxim "private vices are public benefits."[30] Thus, economic order is supposed to spontaneously emerge from free competition of individuals and businesses and this mechanism would be hindered by authoritarian regulations and rigid norms.

Liberal philosophical doctrine is divided on the legitimization of individual liberty. For Emmanuel Kant, it takes its source in a natural right. At the opposite end of the spectrum, the utilitarian vision of Jeremy Bentham and John Stuart Mill denies the existence of natural rights and considers that individual freedom is an essential condition for the greatest number of individuals in a society to have maximum happiness, identified with pleasure and the absence of pain.[31] John Stuart Mill pointed out that the only desirable end is happiness, and the only evidence that something is desirable is that "people do actually desire it."[32] Thus, the satisfaction of individual desires constitutes the basis of modern liberal morality. As everyone may have different desires that change over time, this inevitably leads to a deep fragmentation, literally an atomization, of ethical norms, making any consensual ethical judgment extremely problematic and introducing the basis for ethical relativism.

The objection can be made to this conclusion that there are general texts seen as consensual in the field of ethics, such as, for example, the Universal Declaration of Human Rights. However, this

[25] C. J. Vörösmarty, *et al.*, "Global Threats to Human Water Security and River Biodiversity," *Nature* 467, no. 7315 (2010): 555–61, https://doi.org/10.1038/nature09440.

[26] Stephen J. Del Grosso and Michel A. Cavigelli, "Climate Stabilization Wedges Revisited: Can Agricultural Production and Greenhouse-Gas Reduction Goals Be Accomplished?," *Frontiers in Ecology and the Environment* 10, no. 10 (2012): 571–78, https://doi.org/10.1890/120058.

[27] Aktar, Sengupta, and Chowdhury, "Impact of Pesticides Use in Agriculture" (ref. 22).

[28] Lutz Bornmann, "Measuring the Societal Impact of Research.," *EMBO Reports* 13, no. 8 (2012): 673–76, https://doi.org/10.1038/embor.2012.99.

[29] Adam Smith, *An Inquiry into the Nature and the Causes of the Wealth of Nations* (1776), *The Glasgow Edition of the Works and Correspondence of Adam Smith* (London: W. Strahan and T. Cadell, 1776), https://doi.org/10.1057/9780230291652.

[30] Bernard Mandeville, *The Fable of the Bees: or, Private Vices, Publick Benefits* (London: Tonson, 1714).

[31] J. Bentham, *An Introduction to the Principles of Morals and Legislation* (London: T. Payne and Son, 1789).

[32] John Stuart Mill, *Utilitarianism* (London: Parker, Son & Bourn, 1863), 52.

declaration has no binding value and its frequent violation by many governments raises questions as to its real acceptance as a universal standard. Thus, a very strong ethical consensus, such as condemning the crimes of Nazi scientists, seems the exception rather than the rule.[33]

The fragmentation of ethical norms resulting from the liberal vision logically obscures what constitutes the general good and leads many to consider that it is only an empty concept. The reference to the general good even comes to be considered as a tool serving totalitarian politics. For example, the sociologist Helmut Willke wrote in 2008 in the *Journal of Business Ethics* that "modern secular societies depend on the privatization of morals in order to prevent insolvable conflicts about deeply rooted personal convictions," which is a widespread view. On this basis, he concludes that "any search for an encompassing, more abstract or more general supreme rule, any search for a universal norm necessarily leads into an infinite regress."[34] This apparent exclusion of all morals and thus of social responsibility is not new. Already in 1962, in Capitalism and Freedom, the economist Milton Friedman declared: "Few trends would so thoroughly undermine the very foundations of our free society as the acceptance by corporate officials of a social responsibility other than to make as much money for their stockholders as they possible can. This is a fundamentally subversive doctrine."[35]

In fact, the opinions of Friedman and Willke do not reflect a true exclusion of morality from the public and business sphere. Rather, they reflect their unwavering faith in the liberal axiom making the free market the source of all social well-being and therefore the guarantee of the general good. Still today, the rationality of this position, which largely frames the social code of the liberal business community, continues to be upheld by numerous authors because "recent history has indicated that market economies tend to produce more goods and services and generate a much higher level of public welfare than command economies," and a return to a more authoritarian economy could greatly reduce social welfare over the long term.[36]

The same reasoning is held concerning the requirement of corporate social responsibility. For example, Miles, Munila, and Covin wrote that "forced social responsibility, hereafter referred to as social blackmail, may unintentionally harm social welfare by dramatically reducing returns from innovation and corporate entrepreneurship."[37] Based on this moral self-legitimation, it becomes coherent that, as claimed by Carr, "enterprise

is by its very nature ethical."[38] These authors seem to forget that this overabundance of goods and services required an overexploitation of natural resources and now results in global warming and massive destruction of ecosystems.[39] While the short-term record of economic liberalism is flattering, it will probably be far from the same in the long run.

Faced with the dangerous idea of imposing on companies a principle of sustainable development (i.e., that meets the needs of the present generation without compromising the ability of future generations to meet their needs), Willke retorts that "we do not know what it takes to achieve wellbeing for future generations" and that "all aspirations to safeguard the wellbeing of future generations, the integrity of the ecosystem and the needs of future worlds are highly pretentious because of the temporal complexity of a society of organizations."[40] This view is obviously fatal to any form of political choice in favor of the general good. Due to the diversity of beliefs and desires of individuals and the necessity to preserve the fundamental right to individual liberty, the very notion of the general good becomes an avatar of public morality and consequently is "an exceedingly dangerous commodity inviting fundamentalism, righteousness and the tyranny of good intentions."[40]

Of course, Friedman's doctrine and Willke's position, although often implicitly shared by many philosopher defenders of individual freedoms, are rather extreme and controversial. Social responsibility, environmental ethics and sustainability emerged in the business literature during the 1970s and 1980s and are now often presented by numerous authors as active participants in the business decision process.[41] However, it is feared that business ethics is only a reactive strategy designed to maintain legitimacy, garner societal support and divert demands for greater responsibility. It is frequently recalled that there is "no legal way for corporate executives to reduce their firms' adverse environmental impacts at the short-term expense of shareholders without risking civil litigation charging them with violating their fiduciary duties."[42] Thus, in liberal societies, the preservation of free market mechanics remains ultimately guaranteed by law.

From the above, we can conclude that liberal ideology excludes any formal definition of what constitutes the general good. It does not deny its existence but considers that it comes mainly from the action of private companies and therefore from the free market mechanism. The preservation of the latter becomes the main guarantee of the general good.

The race for innovation in liberal societies puts pressure on the actors of innovation

It is well documented that innovation can increase the fitness/competitiveness of private companies.[43] However, when a company introduces an innovation, it not only increases its competitiveness, but also decreases the competitiveness of its

[33] S. G. Post, "The Echo of Nuremberg: Nazi Data and Ethics," *Journal of Medical Ethics* 17, no. 1 (1991): 42–44, https://doi.org/10.1136/jme.17.1.42.

[34] Helmut Willke and Gerhard Willke, "Corporate Moral Legitimacy and the Legitimacy of Morals: A Critique of Palazzo/Scherer's Communicative Framework," *Journal of Business Ethics* 81, no. 1 (2008): 27–38, on 30, https://doi.org/10.1007/s10551-007-9478-1.

[35] Milton Friedman, *Capitalism and Freedom*, *Capitalism and Freedom* (Chicago: University of Chicago Press, 1962), 133, https://doi.org/10.4324/9781912281107.

[36] Morgan P. Miles, Linda S. Munilla, and Jeffrey G. Covin, "Innovation, Ethics, and Entrepreneurship," *Journal of Business Ethics* 54 (2004): 97–101, on 100.

[37] Morgan P. Miles, Linda S. Munilla, and Jeffrey G. Covin, "The Constant Gardener Revisited : The Effect of Social Blackmail on the Marketing Concept, Innovation, and Entrepreneurship," *Journal of Business* 41, no. 3 (2002): 287–95, on 288, https://doi.org/10.1023/A:1021241129501

[38] Patricia Carr and Max Weber, "Revisiting the Protestant Ethic and the Spirit of Capitalism : The Relationship Understanding between Ethics and Enterprise," *Journal of Business* 47, no. 1 (2009): 7–16, on 8, https://doi.org/10.1023/A:1026232726129

[39] Iselin Medhaug, *et al.*, "Reconciling Controversies about the 'Global Warming Hiatus,'" *Nature* 545, no. 7652 (2017): 41–47, https://doi.org/10.1038/nature22315; Lewis and Maslin, "Defining the Anthropocene" (ref. 23).

[40] Willke and Willke, "Corporate Moral Legitimacy and the Legitimacy of Morals" (ref. 34), 34.

[41] Fiona Tilley, "Small Firm Environmental Ethics: How Deep Do They Go?" *Business Ethics: A European Review* 9, no. 1 (2000): 31–41, https://doi.org/10.1111/1467-8608.00167; Tom E. Thomas and Eric Lamm, "Legitimacy and Organizational Sustainability," *Journal of Business Ethics* 110, no. 2 (2012): 191–203, https://doi.org/10.1007/s10551-012-1421-4; Guido Palazzo and Andreas Georg Scherer, "Corporate Legitimacy as Deliberation: A Communicative Framework," *Journal of Business Ethics* 66, no. 1 (2006): 71–88, https://doi.org/10.1007/s10551-006-9044-2; Lindsay J. Thompson, "The Global Moral Compass for Business Leaders," *Journal of Business Ethics* 93, no. SUPPL. 1 (2010): 15–32, https://doi.org/10.1007/s10551-010-0624-9.

[42] Thomas and Lamm, "Legitimacy and Organizational Sustainability" (ref. 42), 194.

[43] Elena Cefis and Orietta Marsili, "A Matter of Life and Death: Innovation and Firm Survival," *Industrial and Corporate Change* 14, no. 6 (2005): 1167–92, https://doi.org/10.1093/icc/dth081; M. Berk Talay and Janell D. Townsend, "Do or Die: Competitive Effects and Red Queen Dynamics in the Product Survival Race," *Industrial and Corporate Change* 24, no. 3 (2015): 721–38, https://doi.org/10.1093/icc/dtv017; Pamela J Derfus, *et al.*, "The Red Queen Effect: Competitive Actions and Firm Performance" 51, no. 1 (2016): 61–80.

rivals. This idea is already present in Schumpeter's concept of innovation as creative destruction.[44] Innovative firms bring new technology into the economy, but this destroys stagnant companies. Rival companies must then respond to that innovation with their own innovations to survive in the marketplace. This innovation race exacerbates the need for innovation, leading companies to consider that the freedom to innovate is indispensable to their survival. Baumol notes: "Under capitalism, innovative activity . . . becomes mandatory, a life-and-death matter for the firm."[45] However, survival of firms is not ensured just by innovating more and faster, but by producing innovation that fits with their competitive environment. Like for biological entities, an innovation increases the fitness of a company only if it allows it to better adapt to its environment. As the environment in a globalized economy is highly complex and unpredictable, the effect of an innovation always remains uncertain and often short-lived, which drives companies to innovate constantly to maintain their position on the market.

It is interesting to note that this race for innovation is also found at the level of academic research. In recent decades, a new model has emerged in the United States and the UK for the organization of scientific research and has progressively imposed itself in most universities and research funding agencies. This model is based on increased evaluation of researchers using objective and standardized criteria. These criteria measure international visibility, mainly based on the number of citation, and scientific productivity by the number of articles published.[46] Financial resources are concentrated on an elite group of researchers meeting those criteria, which generates a highly competitive dynamic between researchers, as illustrated by the famous "publish or perish" dictum. This new model is also accompanied by strong pressure from states to increase cooperation between universities and private companies and to favor the implementation of business techniques in higher education and research. The Lisbon Strategy, presented in 2011 by the European Commission, is very clear. This strategy aims to make the European Union (EU) "the most competitive and dynamic knowledge-based economy in the world." To achieve this "partnership and cooperation with business should be viewed as a core activity of higher education institutions."[47] Thus, after teaching and research, the production of innovation to fuel the economy becomes officially the new third mission of universities. This entrepreneurial mission replaces the poorly defined mission of "service to society," which included popularizing knowledge and making it available to the public. But how best to serve the general good in a liberal society that feeds the economy?

Thus, the arms race, sometimes also called Red Queen dynamic, between private companies imposed by the liberal economy, as well as the competition for funding between academic research teams, leads the upstream and downstream actors of the innovation process to consider that producing innovation is essential for their own survival, which is not very favorable ground for stimulating reflection on the ethical aspects of research as well as on the possible negative effects of innovation.[48]

Liberalism promotes a new mode of knowledge production

From the above, we can conclude that in modern societies the ethical control of innovation is closely shaped by liberal ideology. Ethical rules are no longer fixed by a notion of right and wrong imposed by religions, philosophy or cultures. Moreover, ethical control must imperatively consider the private interests of companies because it is by their action that the general good is achieved. As a result, ethical standards have been replaced by a complex system of continuous negotiations between all stakeholders leading to what is considered an "ethical consensus" based on the interests and values of each. We must therefore now examine in greater detail the liberal-based theories that legitimate and formalize this process of permanent consultation into the production of scientific knowledge and innovation.

In 1995, Gibbons, et al., presented a theory based on the division of knowledge production into two main modes.[49] It often serves as a framework for reflection in research funding and regulation policies. "Mode 1" refers to the traditional linear production of knowledge established since World War II: innovations are produced in universities and transferred to industry. Gibbons, et al., described the emergence of a new mode of knowledge production, termed "mode 2," where innovations result from nonlinear collaborative interactions between academia, industry and governments. In mode 2, innovations are created in a context of application. Ideally, conceptual discovery and technological application overlap to produce economically and societally useful innovation.

In 2000, Etzkowitz and Leydesdorff proposed a general model for mode 2 knowledge production based on the relations between government, universities and industry, termed the "Triple Helix model."[50] They noted that the nature of the relations between these actors can vary depending on the country. Communist countries, such as the former USSR, developed a policy system where the government controls industry and academic research. In contrast, the policy system dominant in the United States and the UK, and which inspired Europe, is characterized by an overlapping of government, universities and industry, with each taking the role of the other and with multiple hybrid organizations emerging at the interfaces.

It should be noted that in liberal mode 2 the boundaries between the different actors are intended as dynamic and to be erased: "What is considered as 'industry,' what as 'market' cannot be taken for granted and should not be reified. Each "system" is defined and can be redefined."[50] This vision justifies, for example, the importance of lobbies within governments as well as the gradual transformation of universities into commercial private companies whose main functions are the production of innovation and students meeting the criteria of industry. In this perspective, the concept of conflicts of interest (i.e., management by the same actor of competing interests) becomes difficult to define as the mixing of genres is becoming the rule and not the exception.

Etzkowitz and Leydesdorff is emblematic of the growing trend in the literature on innovation to consider that mode 2-like forms of knowledge production are the most likely to produce innovation in line with modern liberal society. They consider that mode 1, which sacralizes the autonomy of universities and the independence and universality of science, is only a transitory and unnatural

[44] Schumpeter, *The Theory of Economic Development* (ref. 2).
[45] William J. Baumol, *The Free Market Innovation Machine (Analyzing the Growth Miracle of Capitalism)* (Princeton: Princeton University Press, 2002), 1.
[46] Ernø-Kjølhede and Hansson, "Measuring Research Performance" (ref. 11).
[47] T. Koryakina, C. S. Sarrico, and P. N. Teixeira, "Universities' Third Mission Activities," in *The Transformation of University Institutional and Organizational Boundaries* (Rotterdam: Sense, 2015), 1–241, on 64, https://doi.org/10.1007/978-94-6300-178-6.
[48] Talay and Townsend, "Do or Die" (ref. 44); Derfus, *et al.*, "The Red Queen Effect" (ref. 44).

[49] Michael Gibbons, *et al.*, *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies* (London: SAGE Publications, 1995), https://doi.org/10.2307/2076669.
[50] Henry Etzkowitz and Loet Leydesdorff, "The Dynamics of Innovation: From National Systems and 'Mode 2 'to a Triple Helix of University–Industry–Government Relations," *Research Policy* 29 (2000): 109–23.

system that developed to protect science from corruption under Nazi or communist doctrine. They presented mode 2 as the natural format of knowledge production before its academic institutionalization. Unsurprisingly, they concluded that the etatistic mode 2 model, inspired by communist ideology, is a failed developmental model where initiatives and innovation were discouraged rather than encouraged. In contrast, the liberal mode 2 is view as self-organized, non-deterministic and non-linear, and thus as a highly adaptive complex system able to continuously integrate and differentiate, both locally and globally. It should be noted that this liberal mode 2 of knowledge production is largely based on the same assumptions as the free market theory governing liberal economy. The mechanics of free competition are thought to solve all problems and regulation is considered as deleterious. Thus, mode 2 could be considered as an extension of the theory of the free market to the field of knowledge production.

Since then, multiple variants of the Triple Helix model have been proposed. For example, Carayannis and Campbell proposed to add a fourth major player to the Triple Helix, the "media-based and culture-based public and civil society," formalizing a "Quadruple Helix model" and a "mode 3" of advanced knowledge production. Mode 3 underscores the need for pluralism in the production of knowledge, integration of multiculturalism and the arts, multiplication of stakeholders and interconnectivity to form an "innovation ecosystem." This heterogeneity of stakeholders is considered as essential to promoting creativity and leading to new knowledge and innovation. According to the authors, mode 3 also key to a "democracy of knowledge," a metaphor that underscores the need for a "democratic approach to innovation."[51] Thus, at a higher level than in Etzkowitz and Leydesdorff, we find a tendency to propose interconnection of all the components of society to produce socially and economically desirable knowledge and innovation. In mode 3, the great heterogeneity and multiculturalism of the stakeholders serve to guarantee respect for democratic values and even due consideration of the imperative of sustainable development. And the complexity of the interactions between stakeholders seems presented as being an intrinsic guarantee of efficient knowledge production.[52]

The issue of guaranteeing the general good: some stakeholders appear to be more equal than others

The Triple Helix model and the models that derive from it evade the major problem of guaranteeing the general good. For a true ethical consensus (*i.e*., reflecting the existence of a general agreement guaranteeing the interest of the greatest number) to emerge from the interactions between the stakeholders, there must be a certain equilibrium between them. In practice, however, like in the free commercial market, nothing ensures the equality of different private or public stakeholders interacting to build an ethical consensus. Social consultation leading to ethical consensus is therefore a free competition for influence. Consequently, if a stakeholder has means of pressure that are far superior to those of the other parties, it can impose its views unilaterally while maintaining the democratic appearance of the process. Absolutely nothing ensures that the general interest will systematically prevail in this type of consultation.

During the second half of the twentieth century, the globalization of the economy has led to the emergence of sprawling multinational private companies. These companies appear able, independently or in association, to manipulate governments, governmental organizations and public opinion through extensive lobbying and media campaigns, in order to escape national legislation and even influence the development of new legislation in favor of their own interest. This phenomenon has been particularly well documented regarding the tobacco industry), but it is obviously not limited to it.[53] We will look at some examples in order to measure the extent of the phenomenon and the problems it poses from the point of view of an ethical regulation of innovation.

The World Health Organization (WHO) estimates that tobacco was responsible during the twentieth century for more than 100 million deaths, more than all wars during the same period. The WHO estimates that, globally, smoking causes over $500 billion in economic damage each year. The tobacco industry has been responsible for more than six million deaths each year since 1990.[54] It is important to understand that a cigarette is not simply tobacco. It cannot be considered as a natural product that is simply marketed and distributed by the tobacco industry. Cigarettes are high technology products that are the result of numerous technical innovations. The tobacco industry was the first to analyze and understand the pharmacology of nicotine and developed its products on the premise that nicotine is the critical and key psychoactive drug that causes addiction.[55] Cigarettes have been optimized to generate the strongest addiction possible among its users. It is clearly established that tobacco addiction results from the dopamine-dependent addictive properties of nicotine, the product design, and wise and expensive marketing campaigns.[56] For decades, tobacco companies have used deceptive research and marketing practices to manipulate the public and cast doubt on legitimate scientific evidence connecting tobacco use with serious disease.[57] A striking example of this manipulation are low-yield cigarettes, supposed to be safer than regular cigarettes, which is obviously not the case as smokers compensate by smoking them more intensely.[58] Recently, e-cigarettes have been presented by the tobacco industry as a new technological innovation that reduces the toxicity associated with tobacco combustion and facilitates weaning. In fact,

[51] Elias G. Carayannis and David F. J. Campbell, *Mode 3 Knowledge Production in Quadruple Helix Innovation Systems* (New York: Springer, 2012), 1, https://doi.org/10.1007/978-1-4614-2062-0_1.

[52] Elias G. Carayannis, David F. J. Campbell, and Scheherazade S. Rehman, "Mode 3 Knowledge Production: Systems and Systems Theory, Clusters and Networks," *Journal of Innovation and Entrepreneurship* 5, no. 1 (2016): 17, https://doi.org/10.1186/s13731-016-0045-9.

[53] Elisa Ong and Stanton Glantz, "Tobacco Industry Effort Subverting the International Agency for Research on Cancer's Secondhand Smoke Study," *Lancet* 355 (2000): 1253–59; Patricia A. McDaniel, Gina Solomon, and Ruth E. Malone, "The Tobacco Industry and Pesticide Regulations: Case Studies from Tobacco Industry Archives," *Environmental Health Perspectives* 113, no. 12 (2005): 1659–65, https://doi.org/10.1289/ehp.7452; Patricia A. McDaniel, Gina Intinarelli, and Ruth E. Malone, "Tobacco Industry Issues Management Organizations: Creating a Global Corporate Network to Undermine Public Health," *Globalization and Health* 4 (2008): 1–18, https://doi.org/10.1186/1744-8603-4-2; Thilo Grüning, *et al*., "Tobacco Industry Attempts to Influence and Use the German Government to Undermine the WHO Framework Convention on Tobacco Control," *Tobacco Control* 21, no. 1 (2011): 30–38, https://doi.org/10.1136/tc.2010.042093.

[54] Marissa B. Reitsma, *et al*., "Smoking Prevalence and Attributable Disease Burden in 195 Countries and Territories, 1990–2015: A Systematic Analysis from the Global Burden of Disease Study 2015," *The Lancet* 389, no. 10082 (2017): 1885–1906, https://doi.org/10.1016/S0140-6736(17)30819-X.

[55] Jack E. Henningfield, Christine A. Rose, and Mitch Zeller, "Tobacco Industry Litigation Position on Addiction: Continued Dependence on Past Views," *Tobacco Control* 15, SUPPL. 4 (2006): 27–36, https://doi.org/10.1136/tc.2005.013789.

[56] W. Berrettini, "Nicotine Addiction," *The American Journal of Psychiatry* 165, no. 9 (2008): 1089–92, https://doi.org/10.1176/appi.ajp.2008.08050780; Carrie M. Carpenter, Geoffrey Ferris Wayne, and Gregory N. Connolly, "The Role of Sensory Perception in the Development and Targeting of Tobacco Products," *Addiction* 102, no. 1 (2007): 136–47, https://doi.org/10.1111/j.1360-0443.2006.01649.x.

[57] Pascal A. Diethelm, Jean Charles Rielle, and Martin McKee, "The Whole Truth and Nothing but the Truth? The Research That Philip Morris Did Not Want You to See," *Lancet* 366, no. 9479 (2005): 86–92, https://doi.org/10.1016/S0140-6736(05)66474-4.

[58] David Hammond, Neil E. Collishaw, and Cynthia Callard, "Secret Science: Tobacco Industry Research on Smoking Behaviour and Cigarette Toxicity," *Lancet* 367, no. 9512 (2006): 781–87, https://doi.org/10.1016/S0140-6736(06)68077-X.

several studies have consistently shown that young e-cigarette users are more likely than those who have never used e-cigarettes to subsequently start smoking cigarettes.[59] Although the malfeasance of the tobacco industry is well known, the fight against tobacco consumption remains mainly limited to consumer information and product taxation.

The same reasoning can be held for the consumption of alcohol, which is considered the third most important modifiable risk factor for death and disability worldwide, but also for ultra-processed foods that offer higher profits for multinational food and beverage companies than basic food but favor obesity and higher rates of chronic diseases.[60] The current costs of obesity alone are estimated at about $2 trillion annually from direct health-care costs and lost economic productivity. Moreover, the big food industry also drives agriculture towards animal source foods that consume great amounts of energy and generate methane and other waste products.[61] This food policy is in no way motivated by the general good and benefits mainly certain multinational companies. However, under the influence of lobbying by these companies, it is gradually imposed on consumers and, despite its cost to health and the environment, it is heavily subsidized by governments.[62]

When will a dividend tax based on considerable damage to the community be imposed on tobacco, alcohol and big food industries? Such an approach would be unthinkable in our liberal economy because the consumption of tobacco, alcohol or ultra-processed foods fully satisfies the principle of liberal morality which considers that the satisfaction of individual desires constitutes the basis of morality, even if this desire has been induced and is the result of manipulation.

The consumption of alcohol, tobacco, and ultra-processed food is often presented as an individual choice that impacts only the individual. However, the global impacts on society are well proven. Alcohol can lead to risky behavior that can cause harm to others, and passive smoking is as harmful as active smoking. Moreover, in societies that share the costs of health care, any individual pathology represents a cost for society as a whole. But we can nevertheless examine one last example, pollution, whose adverse effects are not at all the consequence of an individual choice.

Pollution caused by industrial activity, transport and agriculture has become the largest environmental cause of disease and premature human death in the world today. The Lancet Commission on Pollution and Health concluded that "diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015—16 % of all deaths worldwide— three times more deaths than from AIDS, tuberculosis, and malaria combined and 15 times more than from all wars and other forms of violence."[63] Welfare losses due to pollution are estimated to amount to $4.6 trillion per year. As a result, it is well established that pollution prevention policies are highly cost-effective. Despite this, pollution control is rarely a priority for governments and laws to limit pollution are frequently violated on a large scale, even in the most developed countries. For example, in 2015, the US Environmental Protection Agency (EPA) alleged that Volkswagen Group of America (VW) violated the Clean Air Act by developing and installing emissions control system defeat devices in numerous 2009–2015 model vehicles with diesel engines. In the United States, it has been estimated that excess pollutant emissions resulting from this massive fraud caused early deaths and high morbidity.[64] When monetizing, the social cost is estimated at about $450 million for the 2008–2015 period in the USA.

Examples of the inability of states or supranational governmental organizations, such as the EU, to enforce the laws regulating economic activity, consumption of products impacting health and the use of many substances, such as certain pesticides and endocrine disruptors whose toxicity to humans or the environment is reasonably suspected or even proven, are sufficiently numerous and documented to refute the idea that the examples presented above are exceptional and not symptomatic of our deregulated economic system. The systemic reasons for this inertia to act in favor of the general good are mainly the policy influence of powerful commercial actors, the liberal ideology that postulates that the free market is the only guarantor of the general good and inadequate political leadership and governance.

These problems of an imbalance between the different stakeholders and rejection of any regulation restricting free enterprise are very general and not limited to areas related to public health. For example, it is striking that more than 84 % of known marine genetic resources have been patented by private companies, 47 % of which by a single company, while universities and their partners have only patented 12 %.[65] This growing privatization of resources is not limited to our planet and becomes universal. The Commercial Space Launch Competitiveness Act of 2015 explicitly allows US citizens to "engage in the commercial exploration and exploitation of space resources," which departs considerably from the spirit of the International Space Treaty of 1967, which saw space as a common good that no one can appropriate: "Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means" (Article II).[66] These are typical examples of major resource privatization and the demonstration of a total imbalance between the main actors of innovation in the Triple Helix model. Private companies are, in practice, frequently able to unilaterally impose their views and their private interests on governmental and academic actors.

We can therefore conclude that, in the context of dominant liberal ideology, globalization of the economy and powerful multinational private companies, it becomes difficult to seriously consider the possibility that consensual ethical control of innovation, guaranteeing the respect of the general good, will simply emerge from free interactions between the actors and stakeholders of innovation. Thus, truly effective ethical regulation

[59] Samir Soneji, *et al.*, "Association between Initial Use of E-Cigarettes and Subsequent Cigarette Smoking among Adolescents and Young Adults a Systematic Review and Meta-Analysis," *JAMA Pediatrics* 171, no. 8 (2017): 788–97, https://doi.org/10.1001/jamapediatrics.2017.1488; Shannon Lea Watkins, Stanton A. Glantz, and Benjamin W. Chaffee, "Association of Noncigarette Tobacco Product Use with Future Cigarette Smoking among Youth in the Population Assessment of Tobacco and Health (PATH) Study, 2013-2015," *JAMA Pediatrics* 172, no. 2 (2018): 181–87, https://doi.org/10.1001/jamapediatrics.2017.4173.

[60] World Health Organization, *Global Status Report on Alcohol and Health 2014*, ed. Vladimir Poznyak and Dag Rekve (Geneva: World Health Organization, 2014), https://www.who.int/substance_abuse/publications/alcohol_2014/en/; Boyd A. Swinburn, *et al.*, "The Global Syndemic of Obesity, Undernutrition, and Climate Change: *The Lancet* Commission Report," *The Lancet* 6736, no. 18 (2019): 791–846, https://doi.org/10.1016/S0140-6736(18)32822-8.

[61] Swinburn, *et al.*, "The Global Syndemic of Obesity, Undernutrition, and Climate Change" (ref. 62).

[62] David Stuckler and Marion Nestle, "Big Food, Food Systems, and Global Health," *Plos Medicine* 9, no. 6 (2012): 4–7, https://doi.org/10.1371/journal.pmed.1001242.

[63] Philip J. Landrigan, *et al.*, "The Lancet Commission on Pollution and Health," *Lancet* 6736, no. 17 (2017): 1–51, on 1, https://doi.org/10.1016/S0140-6736(17)32345-0.

[64] Guillaume P. Chossière, *et al.*, "Impact of the Volkswagen Emissions Control Defeat Device on US Public Health," *Environmental Research Letters* 10, no. 11 (2015): 114005, https://doi.org/10.1088/1748-9326/10/11/114005.

[65] Robert Blasiak, *et al.*, "Corporate Control and Global Governance of Marine Genetic Resources," *Science Advances* 4, no. 6 (2018): 1–7, https://doi.org/10.1126/sciadv.aar5237.

[66] United Nations Office for Disarmament Affairs, "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," available: http://disarmament.un.org/treaties/t/outer_space/text (accessed 9 Feb. 2020).

of innovation will come about first and foremost through major ideological change and questioning of our economic model and ideology.

What are the problems of ethical regulation of basic scientific research in terms of scientific methodology?

We have thus far considered the main problems posed by globalization, the emergence of technology-derived global threats, the multicultural nature of modern societies and liberal ideology on the ethical control of innovation. However, scientific knowledge can be considered as a common good and a source of many societal benefits.[67] For example, germ theory of disease, developed by Louis Pasteur and Robert Koch in the nineteenth century, has had many major applications such as food preservation (pasteurization), sterilization in hospitals, and vaccination. This later has saved millions of lives in a century.[68] In addition, scientific knowledge is also indispensable for determining the effects of innovations, as for example in the case of CFCs. Thus, it is important, in the general good but also in the interest of private companies who take advantage of technological innovations, to also look at the compatibility between ethical regulation and scientific methodology to avoid a loss of efficiency of the latter.

In his famous 1942 essay, sociologist Robert K. Merton identified four institutional imperatives forming the ethos (*i.e*., the ideals) of the modern scientific community: communalism (free circulation of scientific results), universalism (rejection of religious, philosophical and cultural biases), disinterestedness (researchers do not seek personal profit), and organized skepticism (systematic peer review of scientific works). Merton stressed, “The acceptance or rejection of claims entering the lists of science is not to depend on the personal or social attributes of their protagonist; his race, nationality, religion, class, and personal qualities are as such irrelevant.”[69] In striking contrast, mode 2 of knowledge production described by Gibbons, et al., explicitly formalizes the introduction of private interests into the process of basic scientific research: “Knowledge is always produced under an aspect of continuous negotiation and it will not be produced unless and until the interests of the various actors are included,” and in the criteria used to determine the quality of scientific work: “Quality in Mode 1 is determined essentially through the peer review judgments about the contributions made by individuals” and “In Mode 2 additional criteria are added through the context of application which now incorporates a diverse range of intellectual interests as well as other social, economic or political ones.”[70]

Mode 2 constitute a great rupture with Mertonian norms. Interestingly, Gibbons, et al., justify this rupture by the fact that “In comparison with Mode 1, Mode 2 is more socially accountable and reflexive. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localized context” and “working in the context of application increases the sensitivity of scientists and technologists to the broader implications of what they are doing.”[70] Mode 2 is therefore supposed to promote “good science” that is more ethical and respectful of democratic governance. It remains to be determined whether this “good science” preserves the basic qualities of science and if mode 2 can be safely applied to basic research.

Could new modes of knowledge production favor the rise of false science?

Modes 2 and 3 consider that producing knowledge in an application context, in partnership with industry, by involving as many partners from civil society as possible in the research process, is the most effective way to produce economically and socially useful innovations. In this perspective, it is obvious that the value of the results of research becomes the critical element to evaluate it. While in mode 1 the only requirement for the results of research is its veracity, i.e. its ability to describe, predict and manipulate reality.

As theorized by Karl Popper, the refutability of a scientific theory constitutes the demarcation between science and belief or pseudoscience.[71] Consequently, modern scientific methodology in natural science relies mainly on testing the fit of scientific hypotheses with reality. This confrontation with reality is based on observation in natural conditions and laboratory experimentation. At no time is the validation/refutation process of a scientific hypothesis likely to be influenced by its value in terms of religion, culture, philosophy or politics. In the study of natural phenomena, the superiority of the experimental approach in relation to a purely rationalist approach that regards reason as the chief source and test of knowledge is obvious. The polemic on spontaneous generation is emblematic in this respect. Philosophers have debated the reality of spontaneous generation since Aristotle. It was enough for Louis Pasteur to carry out a series of experiments with gooseneck bottles to return spontaneous generation to the oblivion of science.

Of course, this ideal of neutrality is never truly achieved at the individual level. A researcher is necessarily influenced by many factors that can alter his/her judgment. Moreover, experimental models are always a simplification of reality and, because of the researchers’ choices in their design, are social constructions. This phenomenon has long been highlighted by the works of the partisans of epistemological constructivism like Bruno Latour and Steve Woolgar.[72] And, numerous studies have demonstrated that biases related to the individuals or method used are inevitable. For example, the existence of biases in randomized clinical trials is now well documented, even though this method has long been considered as a panacea to eliminating them.[73] Modern scientific methodology partly solves this important problem of biases through epistemic diversity and networking.

According to Paul Feyerabend, the complexity of the real world makes its analysis impossible by a simple and unique method.[74] As a result, the combination of several methods often appears to be the most effective way to investigate natural phenomena. In biology, it has become more and more common to combine “reductionist” and “systems biology” approaches to analyze a phenomenon, although the two types of approaches are based on a radically different ontological vision.[75] Reductionism postulates that complex systems or phenomena can be understood by the analysis of their simpler components in an isolated and well

[67] Arturo Casadevall and Ferric C. Fang, “Revolutionary Science,” *MBio* 7, no. 2 (2016): 1–6, https://doi.org/10.1128/mBio.00158-16.

[68] Sandra W. Roush, *et al.*, “Historical Comparisons of Morbidity and Mortality for Vaccine-Preventable Diseases in the United States,” *Journal of the American Medical Association* 298, no. 18 (2007): 2155–63, https://doi.org/10.1001/jama.298.18.2155.

[69] Robert K. Merton, “The Normative Structure of Science” (orginally published in 1942 as “Science and Technology in a Democratic Order”), in Robert K. Merton, *The Sociology of Science: Theoretical and Empirical Investigations*, ed. Norman W. Storer (Chicago: University of Chicago Press, 1972), 267–78, on 270.

[70] Gibbons, *et al.*, *The New Production of Knowledge* (ref. 50), p. 8.

[71] Karl R. Popper, *The Logic of Scientific Discovery* (New York: Basic Books, 1959).

[72] Bruno Latour and Steve Woolgar, *Laboratory Life: The Social Construction of Scientific Facts*, *New Media and Society* (Princeton: Princeton University Press, 1979).

[73] Miriam Solomon, “Just a Paradigm: Evidence-Based Medicine in Epistemological Context,” *European Journal for Philosophy of Science* 1, no. 3 (October 2011): 451–66, https://doi.org/10.1007/s13194-011-0034-6.

[74] Paul Feyerabend, *Against Method* (London: New Left Books, 1975).

[75] Ferric C. Fang and Arturo Casadevall, “Reductionistic and Holistic Science,” *Infection and Immunity* 79, no. 4 (2011): 1401–4, https://doi.org/10.1128/IAI.01343-10.

controlled environment. When pushed to the extreme, this approach considers that any phenomenon can be reduced to the molecular level. A classic example in biology is the analysis of cell lines in vitro. In contrast, systems biology postulates that biological agents composing a system are deeply interconnected and that this interconnection allows the emergence of behaviors that are absent when the system is incomplete. So, to understand the structure and dynamics of the system, the agents that constitute it must be examined in the intact system and in the most natural conditions possible. This lead, for example, to analysis of the behavior of cells in living animals. In medicine, translational research emerged in the early 2000s and constitutes a mix of evidence-based medicine (or empiric medicine) based on randomized controlled trials and mechanistic reasoning based on experimental science.[76] Thus, modern scientific methodologies therefore use many approaches, regardless of their ontological compatibility. Of course, it is obvious that it is not enough to mix any number of approaches to increase the effectiveness of scientific research and reduce the limitations and biases inherent to each approach. Diversity is not a magic recipe. An approach must be proven in its ability to produce verifiable knowledge before it can be associated with other methods. For example, there is little chance that the practice of divination by shamanic trance, though the method dates back to antiquity and is still very present in many cultures, will improve in any way the efficiency of scientific research. Consequently, Feyerabend's famous "anything goes" should not be taken literally but as an incentive not to be dogmatically limited to one single approach for ideological reasons.[77]

Networking in modern scientific methodology acts on many levels to detect and fight the presence of bias. First, the publication of scientific works requires that they stand up to the rigorous examination of several anonymous specialists. This is what constitutes the "peer review process."[78] In recent times, the practice of double-blind review has been used, where the reviewers know neither the names nor the institutions of the authors. Many scientific journals publishing on the internet have also made the decision to publish critical reviews with the article, which significantly increases the transparency of the review process. Second, the value of a scientific hypothesis is never decided based on a single study or a single experimental model. In practice, many independent research teams, composed of researchers of all ages, sexes, cultures and religions, using different technical approaches and experimental models, compare their observations and experimental results. It is important to note that this diversity of researchers is not intended to maximize biases but to identify and neutralize them. For example, the detection of a religious bias in a scientific study is reason enough to reject it even after its publication. In 2016, in response to complaints from researchers, the journal Plos One retracted an article on hand coordination that referred to a "Creator" in interpreting its results.[79] Third, the true validation of a theory often comes from its ability to support the development of applications that can then be tested in the real world. In translational research, this phase of application is sometimes called the "valley of death," because very few mechanistic hypotheses resist this test of reality.[80] It is this incessant process of data comparison and validation as well as attempts to develop and test applications in the real world which makes it possible to constantly improve the mechanistic and predictive value of scientific theories.

The history of science is full of examples suggesting that private commercial interests generate multiple biases that can seriously hijack the process of scientific research. The water memory controversy supporting the homeopathy industry or the false link between autism and vaccination published by Wakefield, et al., have been highly discussed and publicized.[81] Despite this, the involvement of industrial sponsors of scientific research, particularly in clinical trial research, has increased exponentially. In 1980, 32 % of all biomedical research was funded by industry; this figure increased to 62 % in 2000.[82] The involvement of industry partners in research has undoubted benefits, including financial resources and expertise, but poses the problem of conflicts of interest.[83] As defined by Thompson, "A conflict of interest is a set of conditions in which professional judgment concerning a primary interest (such as patient's welfare or the validity of the research) tends to be unduly influenced by a secondary interest (such a financial gain)."[84] A statistically significant association between industry sponsorship and pro-industry conclusions has been reported, demonstrating that partnership with industry can qualitatively influence the research process. Faced with this situation, some authors concluded that the self-reporting of conflicts of interest is not sufficient to ensure integrity in the research,[85] and some even recommended to "isolate research from economic pressure whenever possible."[86]

Regarding the impact of ideology, be it religious, political or philosophical, it is also well accepted that it can introduce an important bias in science. The Lysenko affair, the attempt to produce genetics consistent with communist ideology, is perhaps the best-known example.[87] But it would be very naïve to think that liberal ideology would be neutral and have no direct and detrimental impact on modern scientific research. For example, it seems clear that the liberal conception of the primacy of the

[76] Miriam Solomon, "What Is Translational Medicine?," in *Making Medical Knowledge*, 2015, https://doi.org/10.1093/acprof:oso/9780198732617.003.0007.

[77] Feyerabend, *Against Method* (ref. 77), 23.

[78] Ray Spier, "The History of the Peer-Review Process," *Trends in Biotechnology* 20, no. 8 (2002): 357–58, https://doi.org/10.1016/S0167-7799(02)01985-6.

[79] The-PLOS-ONE-Staff, "Retraction: Biomechanical Characteristics of Hand Coordination in Grasping Activities of Daily Living," *PLoS ONE* 11, no. 3 (2016): e0151685, https://doi.org/https://doi.org/10.1371/journal.pone.0151685.

[80] D. Butler, "Translational Research: Crossing the Valley of Death," *Nature* 453, no. 7197 (2008): 840–42.

[81] E. Davenas, *et al.*, "Human Basophil Degranulation Triggered by Very Dilute Antiserum against IgE," *Nature* 333, no. 6176 (1988): 816–18, https://doi.org/10.1038/332141a0; J. Maddox, J. Randi, and W. W. Stewart, "High-Dilution Experiments a Delusion," *Nature* 334, no. 6181 (1988): 287–90, https://doi.org/10.1038/332141a0; on Wakefield, et al.: Laura Eggertson, "Lancet Retracts 12-Year-Old Article Linking Autism to MMR Vaccines.," *CMAJ* 182, no. 4 (2010): 199–200, https://doi.org/10.1503/cmaj.109-3179.

[82] Justin E. Bekelman, Yan Li, and Cary P. Gross, "Scope and Impact of Interest in Biomedical Research," *Journal of the American Medical Association* 289, no. 4 (2003): 454–65.

[83] Gordon DuVal, "The Benefits and Threats of Research Partnerships with Industry," *Critical Care* 9, no. 4 (2005): 309–10, https://doi.org/10.1186/cc3539.

[84] D. F. Thompson, "Understanding Financial Conflicts of Interest," *The New England Journal of Medicine* 329, no. 8 (1993): 573–76, on 573, https://doi.org/10.1056/NEJM199308193290812.

[85] Richard A. Davidson, "Source of Funding and Outcome of Clinical Trials," *Journal of General Internal Medicine* 1, no. 3 (1986): 155–58, https://doi.org/10.1007/BF02602327; Mark Friedberg, *et al.*, "Evaluation of Conflict of Interest in Economic Analyses of New Drugs Used in Oncology," *Journal of the American Medical Association* 282, no. 15 (1999): 1453–57; Bekelman, Li, and Gross, "Scope and Impact of Interest in Biomedical Research" (ref. 85); Anke Huss, *et al.*, "Source of Funding and Results of Studies of Health Effects of Mobile Phone Use: Systematic Review of Experimental Studies," *Environmental Health Perspectives* 115, no. 1 (2007): 1–4, https://doi.org/10.1289/ehp.9149; Chris S. Bailey, *et al.*, "Industry and Evidence-Based Medicine: Believable or Conflicted? A Systematic Review of the Surgical Literature," *Canadian Journal of Surgery* 54, no. 5 (2011): 321–26, https://doi.org/10.1503/cjs.008610.

[86] Hamilton Moses III and Joseph B. Martin, "Academic Relationships with Industry," *Journal of the American Medical Association* 285, no. 7 (2003): 933–35, on 934, https://doi.org/10.1001/jama.285.7.933.

[87] Nils Roll-Hansen, "The Lysenko Effect: Undermining the Autonomy of Science," *Endeavour* 29, no. 4 (2005): 143–47, https://doi.org/10.1016/j.endeavour.2005.10.003.

individual over society is not foreign to the systematic rejection of the theory of group selection in the science of evolution.[88] More generally, as discussed previously, the strategy of academic research funding, based in part on the precepts of the liberal economy, has generated a highly competitive dynamic between researchers, leading a growing number of them to deviate from scientific deontology and to publish poor quality work or even plagiarized articles, as illustrated by the exponential multiplication in the percentage of articles retracted for fraud or plagiarism.[89] More worrisome yet is the threat of "publish or perish" and the idea that scientific articles are simple commercial products also contributes to the proliferation of predatory journals that publish non peer-reviewed articles under a scientific appearance, demonstrating that the problem of the integrity of scientific research in the face of commercial interests is now general and not confined to particular publicly divisive topics.[90]

Ultimately, the popularization of mode 2 concepts has undoubtedly also contributed to the multiplication and legitimization of movements rejecting the foundations of modern science. Anti-science movements, fighting the theory of evolution, vaccination, anthropogenic global warming, animal experimentation or even the heliocentric theory, have all developed communication strategies based on the denigration of scientific methodology and academic research in general.[91] These strategies involve the use of pseudo-experts to prove the existence of scientific controversies or even conspiracies involving scientists or industry. According to mode 2 principles, these anti-science movements frequently call for the resolution of scientific controversies through public debate combining experts and non-experts representative of all concerned actors of society, arguing that this process is the only one that is compatible with democracy.

Application of mode 2 to basic academic research would mark a tragic regression of scientific methodology

From a methodological point of view, the most fundamental difference between the classical mode 1 and the new popular mode 2 of knowledge production is the treatment given to social bias. Mode 1 recognizes its existence and tries to neutralize it, especially by promoting Mertonian's norms of universalism and skepticism. Conversely, mode 2 aims to maximize social bias and the consideration of private interests and even considers that it is key to producing good science that is respectful of public interest and democratic values. At the extreme, mode 2 defends the idea that the validity of a scientific observation or theory, or even of scientific methodology, can be decided by popular referendum. This point of view has been adopted by opponents of animal experimentation who call for the validity of this experimental method to be judged democratically.[92]

Though it may be attractive for the media, the public and some politicians, this proposal is not acceptable for obvious reasons. First, the history of the tobacco industry's malfeasances shows that it is very easy to manipulate public opinion and governments. The fabrication of doubt and fake news has become a flourishing industry that dominates media and the internet in particular.[93]

Second, studies have documented the existence of cognitive biases caused by belonging to a social group influencing the perception of scientific consensus.[94] People endorse that which reinforces their connection to others with whom they share important commitments. For example, there is a clear political cleavage in the American population concerning acceptance of the anthropogenic causes of global warming. Among Democratic voters, adherence to anthropogenic causes increases with the level of scientific education, while among Republican voters, it decreases.[95] This example suggests that scientifically well-established facts, or the rationality of arguments, have very little influence on our perception of reality when it comes into conflict with the normative effects of political, philosophical or religious ideologies. When acceptance or rejection of a concept becomes entwined with group identity, the risk of social ostracism for the individual is probably costlier than the lack of rationality or the rejection of scientific evidence.

Third, with regard to political speech or commercial advertisements, the form in which a given scientific fact or opinion is presented has a non-negligible impact on its perception by the public. Studies on science communication have shown that extraneous factors, such as the facial appearance of the scientist, the visual imagery associated with communication or the presence of reductive information can influence whether the message is widely discussed and believed or ignored and discredited.[96]

Based on the above, it is difficult to sustain that a popular judgment, or a scientific methodology that deliberately incorporates a maximum of social biases such as mode 2 knowledge production, can lead to true knowledge of reality what constitutes the objective of basic research.

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[88] O T Eldakar and D S Wilson, "Eight Criticisms Not to Make about Group Selection," *Evolution* 65, no. 6 (2012): 1523–26, https://doi.org/10.1111/j.1558-5646.2011.01290.x.Eight.

[89] Ferric C. Fang, R, Grant Steen, and Arturo Cadadevall, "Misconduct Accounts for the Majority of Retracted Scientific Publications," *Proceedings of the National Academy of Sciences* 110, no. 3 (2012): 1136–37, https://doi.org/10.1073/pnas.1220833110; Björn Brembs, *et al.*, "Deep Impact: Unintended Consequences of Journal Rank," *Frontiers in Human Neurosciences* 7 (June 2013): 291, https://doi.org/10.3389/fnhum.2013.00291; R. Grant Steen, Arturo Casadevall, and Ferric C. Fang, "Why Has the Number of Scientific Retractions Increased?" *PLoS ONE* 8, no. 7 (2013): 1–9, https://doi.org/10.1371/journal.pone.0068397.

[90] Piotr Sorokowski, *et al.*, "Predatory Journals Recruit Fake Editor," *Nature* 543, no. 7646 (2017): 481–83, https://doi.org/10.1038/543481a.

[91] Robert T. Pennock, "Creationism and Intelligent Design," *Annual Review of Genomics and Human Genetics* 4, no. 1 (2003): 143–63, https://doi.org/10.1146/annurev.genom.4.070802.110400; Azhar Hussain, *et al.*, "The Anti-Vaccination Movement: A Regression in Modern Medicine," *Cureus* 10, no. 7 (2018): 1–8, https://doi.org/10.7759/cureus.2919; Riley E. Dunlap and Peter J. Jacques, "Climate Change Denial Books and Conservative Think Tanks: Exploring the Connection," *American Behavioral Scientist* 57, no. 6 (2013): 699–731, https://doi.org/10.1177/0002764213477096; Pierre Luc Germain, Luca Chiapperino, and Giuseppe Testa, "The European Politics of Animal Experimentation: From Victorian Britain to 'Stop Vivisection'," *Studies in History and Philosophy of Biological and Biomedical Sciences* 64 (2017): 75–87, https://doi.org/10.1016/j.shpsc.2017.06.004; Kharroubi Amira and Touir Jamel, "The Geocentric Model of the Earth: Physics and Astronomy Arguments," *The International Journal of Science & Technoledge* 4, no. 8 (2016): 57–62; Sven Ove Hansson, "Science Denial as a Form of Pseudoscience," *Studies in History and Philosophy of Science Part A* 63 (2017): 39–47, https://doi.org/10.1016/j.shpsa.2017.05.002.

[92] Germain, Chiapperino, and Testa, "The European Politics of Animal Experimentation" (ref. 94).

[93] Alexander Michael Petersen, Emmanuel M. Vincent, and Anthony LeRoy Westerling, "Discrepancy in Scientific Authority and Media Visibility of Climate Change Scientists and Contrarians," *Nature Communications* 10, no. 1 (2019): 3502, https://doi.org/10.1038/s41467-019-09959-4.

[94] Dan M. Kahan, Hank Jenkins-Smith, and Donald Braman, "Cultural Cognition of Scientific Consensus," *Journal of Risk Research* 14, no. 2 (2011): 147–74, https://doi.org/10.1080/13669877.2010.511246.

[95] Dan M. Kahan, "Climate-Science Communication and the Measurement Problem," *Political Psychology* 36, no. S1 (2015): 1–43, https://doi.org/10.1111/pops.12244.

[96] Ana I. Gheorghiu, Mitchell J. Callan, and William J. Skylark, "Facial Appearance Affects Science Communication," *Proceedings of the National Academy of Sciences* 114, no. 23 (2017): 5970–75, https://doi.org/10.1073/pnas.1620542114; Hélène Joffe, "The Power of Visual Material: Persuasion, Emotion and Identification," *Diogenes* 55, no. 1 (2008): 84–93, https://doi.org/10.1177/0392192107087919; Emily J. Hopkins, Deena Skolnick Weisberg, and Jordan C. V. Taylor, "The Seductive Allure Is a Reductive Allure: People Prefer Scientific Explanations That Contain Logically Irrelevant Reductive Information," *Cognition* 155 (2016): 67–76, https://doi.org/10.1016/j.cognition.2016.06.011.

It is important to note that it is fully legitimate for social consultation to regulate applied research devoted to the development of technological applications. Such technologies are not neutral, as they aim to achieve a specific goal and reflect societal choices and values. But, as many historical examples demonstrate, it is extremely dangerous to influence basic academic research by requiring researchers to take into account what is correct from a religious, philosophical, political, ethnical or gender perspective. These requirements can increase the propensity of researchers to consciously or unconsciously distort reality. One might fear that the permanent establishment of a dominating mode 2 in academic research could constitute a significant regression of quality and efficiency of scientific methodology. The requirement of independence of science, formulated in Michael Polanyi's "Republic of Science" essay, is in no way an old-fashioned concept and should not be confused with a social claim by scientists. It is an unavoidable methodological necessity.[97] If we neglect this requirement, the mathematician Norbert Wiener, who denounced "the degradation of the position of the scientist as an independent worker and thinker to that of morally irresponsible stooge in a science-factory," may well be the prophet of the science of the twenty-first century.[98]

Conclusions

The human species is frequently presented in literature and the media as occupying a very special place in the kingdom of life. Biology, and especially paleontology, reminds us, however, that it would be dangerous to consider that we are not subject to the same contingencies as other living organisms. Species extinction is common, as over 99 % of known species are extinct.[99] The modern human, *Homo sapiens*, belongs to the *Homo* genus of the hominid family. All other species of the genus *Homo*, fifteen of which have been described to date, are extinct. Their disappearance is a reminder of the fact that hominids, even when they have a culture and a complex social organization, are subject, like all biological entities, to intense selection pressures that can lead to their extinction.

The next century will be rich in challenges for *H. sapiens*. We will have to consider the consequences of exponential population growth, aging of the population, reduction of fossil energy resources, massive degradation of ecosystems and rapid climate change. Our species certainly has already faced many challenges, but probably never at such a global level. It will be vital for our survival to be able to make rational decisions, especially regarding the control of technological innovation, keeping in mind that many of our current problems derive from it.[100] On the other hand, because of the importance of innovation to economic growth and public health and the interest of scientific knowledge in risk assessment and decision making, it is also crucial to preserve the efficiency of scientific methodology and, more generally, of the process of scientific knowledge production.

The rapid dissemination of innovations in a globalized world as well as their addictive nature implies that innovations should be mainly controlled anticipatively, and this imperative is plagued by several major problems. At the academic research stage, it is very difficult, if not impossible, to identify, and even more to quantify, the possible societal effects of scientific discoveries and innovation. A great number of innovations, especially those that are disruptive, derived from concepts that are discovered fortuitously, as part of "normal" basic research guided only by curiosity and supported by public funding.[101] Moreover, as extensively discussed below, it is dangerous to impose ethical constraints, be they religious, philosophical, political, or financial, on the aims of basic scientific research. The independence of science should not be confused with social demands on scientists. Instead, it is a methodological requirement. Over the centuries, scientific method has become more efficient thanks not only to the rejection of divine explanations, but also to the rejection of anthropocentrism and all forms of ideological bias. Consequently, fundable projects at the academic research stage should be selected mainly based on the originality and methodological qualities of projects, in agreement with mode 1 production knowledge principles, and not according to expected hypothetical societal gains as recommended by mode 2.

This obviously does not represent a claim for scientific research without constraints, nor for university research without control. First, both basic and applied research projects are carried out within universities. There is no reason that applied research projects should not be subject to ethical control of their goals in accordance with mode 2. Second, the means used to carry out basic research must be subject to a judgment of moral value. For example, the respect of privacy in clinical trials or of animals in experimentation is fundamental. These constraints do not affect the results of the research or their interpretation. What must be avoided is to make value judgments on projects or on results of basic research based on ideological beliefs or private financial interests.

The most rational way to design anticipatory ethical control of innovation, reconciling both social accountability and the requirement of independence of basic research, would therefore be to place this control at the stage of applied research in universities or the research and development stage in industry, as proposed by Flipse, et al.[102] At this stage, the consequences of an innovation are easier to predict, and the financial investments have not yet been too important. This ethical control would require the development of new specific legislation, because it is difficult to expect that the ethical consequences of a project would be considered spontaneously in an environment dominated by the logic of short-term profit.

Generalist scientists will also need to be trained and brought together in expert committees. Innovations are often the result of a multidisciplinary approach and their effects generally affect many fields. Scientists with a broad and multidisciplinary background are therefore best equipped to identify the potential and effects of innovations. In this respect, it would be particularly important at the academic level to bring together knowledge in both the natural and human sciences. The current academic separation between these fields is indefensible and dates back to a time when humans were not considered as part of nature. Currently, unfortunately, research funding strategy requires researchers to become more and more specialized. Researchers only get funding for research projects if their past research gives them expertise in the projects

97 Michael Polanyi, "The Republic of Science. Its Political and Economic Theory," *Minerva,* 1, no. 1 (1962): 54–73.

98 Norbert Wiener, "Rebellious Scientist after Two Years," *Bulletin of the Atomist Scientists* 14 (1948): 338–39, on 338.

99 David M. Raup, "Biological Extinction in Earth History," *Science* 231 (1986): 1528–33; D. M. Raup, "The Role of Extinction in Evolution.," *Proceedings of the National Academy of Sciences* 91, no. 15 (1994): 6758–63, https://doi.org/10.1073/pnas.91.15.6758.

100 Schultz, "Modern Technology and Human Extinction" (ref. 14); Snyder-Beattie, Ord, and Bonsall, "An Upper Bound for the Background Rate of Human Extinction" (ref. 15).

101 Casadevall and Fang, "Revolutionary Science" (ref. 69).

102 Steven M. Flipse, Maarten C. A. van der Sanden, and Patricia Osseweijer, "Midstream Modulation in Biotechnology Industry: Redefining What Is 'Part of the Job' of Researchers in Industry," *Science and Engineering Ethics* 19, no. 3 (2013): 1141–64, https://doi.org/10.1007/s11948-012-9411-6.

submitted. This funding strategy frequently puts researchers in an increasingly narrow field and produces hyper-specialists who are not very curious about what is not their area of expertise. Yet, it is essential to favor true multidisciplinary and the emergence of generalists in science if we hope to improve our ability to anticipate rather than endure the deleterious effects of innovation.

The twentieth century saw the emergence of technologies capable of generating major threats acting at global level even if they are only used locally. Some of these are obvious, like nuclear weapons. But others are much more insidious, such as CFCs. This drastically changes the stakes of innovation ethics. It is no longer just about respecting cultural, religious or philosophical values and norms. It is also about protecting present and future generations. And in some extreme cases, but which have been dangerously becoming more numerous, it is about ensuring the survival of the human species as a whole. Therefore, the ethical control of innovation must stop being local and based on specific cultural, religious or philosophical norms and instead become global and protect the general good. To accomplish this revolution, ethics, to define the general good and identify innovations that may threaten it, must rely on verifiable knowledge likely to convince the greatest number and not on religious, moral or philosophical beliefs that historically have always led to deep divisions.

Take as an example the problem of food security. Demographic growth is leading us inexorably towards a population of nine to ten billion people in 2050, which will significantly increase the demand for food. Current agriculture is presently the main source of climate change and destruction of biodiversity.[103] Reconciling food security and preserving climate and biodiversity are perhaps the greatest challenges facing humanity.[104] For this, we must, among other things, change our modes of food production and our diet, including reducing the consumption of meat. Could a moral argument, such as the one developed by anti-specism and veganism partisans, convince the greatest number to consume less meat? Or are the scientific demonstration of the deleterious effects of too much meat consumption on human health and the impact of livestock on climate change more likely to be persuasive?[105] The future will answer these questions but many historical examples, such as CFCs, demonstrate that scientific arguments play a key role in convincing governments and the public.

Presently, according to the Triple and Quadruple Helix models inspired from liberal ideology, the control of innovation in modern societies results mainly from interactions between universities, industries and government as well as media-based and culture-based public and civil society.[106] This complex consultation process, which is a transposition into the ethical field of the free market mechanism, is supposed to gain in efficiency and move closer to a democratic process by integrating a maximum of stakeholders.

As many examples show, this control has two major flaws. First, it is impossible to integrate all stakeholders, and even less the future generations if they are concerned, into a consultation process when an innovation is likely to act globally and affect all humans. Second, in practice, it is obvious that there is a significant imbalance between the different stakeholders. And this imbalance often prevents the general good from being guaranteed. Large multinational private companies have far more resources than universities or non-governmental organizations representing the public. Governments remain the only organizations capable of imposing on these private companies a respect for the general good.

In this context, the growing loss of scientific expertise in governmental agencies is extremely worrisome.[107] This loss reduces the efficacy of current regulatory laws intended to assure the health and safety of citizens. This phenomenon has many causes. It is partly explained by the chronic underfunding of public basic research and by the low attractiveness for scientists of careers in public service. Moreover, researchers are frequently pushed by the current funding system to find their funding in partnership with private companies, which reduces their independence. This situation is also further aggravated by the "anti-science attitude" of some governments that uses insidious approaches to undermine scientific integrity and weaken the ability of science to participate in regulatory action and governance processes.[108] If one wants true ethical control of innovation, governments and public regulatory agencies must retain high scientific expertise, let their experts speak and act freely and not rely on the expertise of private companies whose motivations are often primarily financial and based on a short-term outlook. Unfortunately, the increasingly common predominance in governments of individuals from the business world suggests that the anti-science attitude is likely to become more widespread in the future.

The position defended by Willke and many other supporters of liberalism that there is no identifiable interest common to all individuals and therefore that the notion of general good is meaningless is not rationally defensible.[109] Survival and health are goals that are necessarily common to all individuals or societies because they are the undisputed prerequisites for the pursuit of any other purpose. Therefore, fostering the conditions necessary for survival and health of the greatest number in the long term should be a unanimous priority. This might seem to be a very minimal basic necessary consensus, but numerous precepts can be derived from the known conditions favoring survival and health. For example, the "One-health" concept underscores that human health must be understood on a global scale and from a global and crosscutting perspective, integrating human health, animal health, plant health, ecosystems health, and biodiversity.[110] This considerably broadens the areas where the issue of human health can serve as a guiding principle. From this point of view, it seems perfectly legitimate that the health guarantee of the greatest number leads to a much greater framing of economic activities

[103] Aktar, Sengupta, and Chowdhury, "Impact of Pesticides Use in Agriculture" (ref. 22); Foley, *et al.*, "Solutions for a Cultivated Planet" (ref. 22); Foley, *et al.*, "Global Consequences of Land Use" (ref. 24); Vörösmarty, *et al.*, "Global Threats to Human Water Security and River Biodiversity" (ref. 25); Del Grosso and Cavigelli, "Climate Stabilization Wedges Revisited" (ref. 26).

[104] H. C. Godfray, *et al.*, "Food Security: The Challenge of Feeding 9 Billion People," *Science* 327, no. 5967 (2010): 812–18, https://doi.org/10.1109/CIS.2016.52.

[105] Giuseppe Lippi, Camilla Mattiuzzi, and Gianfranco Cervellin, "Meat Consumption and Cancer Risk: A Critical Review of Published Meta-Analyses," *Critical Reviews in Oncology/Hematology* 97 (2016): 1–14, https://doi.org/10.1016/j.critrevonc.2015.11.008; Pete Smith, *et al.*, "How Much Land-Based Greenhouse Gas Mitigation Can Be Achieved without Compromising Food Security and Environmental Goals?" *Global Change Biology* 19, no. 8 (2013): 2285–302, https://doi.org/10.1111/gcb.12160.

[106] Etzkowitz and Leydesdorff, "The Dynamics of Innovation" (ref. 51); Carayannis and Campbell, "Mode 3 Knowledge Production" (ref. 53).

[107] V. Eady, *et al.*, "Congress's Attacks on Science-Based Rules," *Science* 348, no. 6238 (2015): 964–66; Andrew A. Rosenberg and Kathleen Rest, "War on Science Agencies," *Scientific American* 318, no. 1 (2018): 8, https://doi.org/10.1038/scientificamerican0118-8; Gretchen T. Goldman, *et al.*, "Ensuring Scientific Integrity in the Age of Trump," *Science* 355, no. 6326 (2017): 696–98, https://doi.org/10.1126/science.aam5733.

[108] Eady, *et al.*, "Congress's Attacks on Science-Based Rules" (ref. 109).

[109] Willke and Willke, "Corporate Moral Legitimacy and the Legitimacy of Morals" (ref. 34).

[110] Delphine Destoumieux-Garzón, *et al.*, "The One Health Concept: 10 Years Old and a Long Road Ahead," *Frontiers in Veterinary Science* 5 (February 2018): 1–13, https://doi.org/10.3389/fvets.2018.00014.

than it does today. Of course, it is obvious that the societal value of all organizational and technical innovation cannot be judged solely based on these criteria. Deep reflection will be necessary to identify other rules, which goes well beyond the scope of this article.

Finally, it is also very important to have an efficient ethical regulation of innovation to rethink the place of science in our societies. In his famous political philosophy work, *The Leviathan*, Thomas Hobbes proposed that "*Science* is the knowledge of Consequences, and dependance [*sic*] of one fact upon another."[111] It reminds those who might have forgotten that scientific research is not just about producing innovation as fuel for the economy. Science also aims to produce a coherent representation of the world, to guide our actions and help us make rational choices. Many examples presented in this article demonstrate that scientific knowledge is essential to establish the causal link between an innovation and its positive or negative effects. Thus, based on Hobbes' vision, we would expect to see the sciences play a key role in the decision-making process in the governance of modern societies. Many studies in the field of knowledge utilization show that this is not so simple.[112] Scientific knowledge seems to rarely participate in the decision-making process itself (instrumental use). It could, however, induce a gradual shift in the conceptual thinking of policymakers (conceptual use), which Carol Weiss called the "enlightenment" function of research.[113] But, it is thought to be used especially to legitimize political decisions (symbolic use), as described through Weiss's "political model."[113]

Several reasons have been proposed to explain this lack of instrumental utilization of scientific knowledge by policymakers. Of course, the exponential growth of specialized scientific knowledge results in a simultaneous increase in ignorance ("knowledge–ignorance paradox").[114] More specifically, however, following Nathan Caplan (the two-communities theory), academic researchers and policymakers "live in separate worlds with different and often conflicting values, different reward systems, and different languages," due to different interests and culture.[115] But an argument often invoked is the inability of science to express itself with a high enough degree of certainty on many science-related issues. However, as discussed previously, scientific uncertainty characterizes most threats related to technology. Thus, effective ethical regulation of innovation inevitably involves the promotion of scientific knowledge in the governance process of our societies but also the discovery of a way to reconcile science, uncertainty and governance. The existence of major global threats excludes that we can simply wait to achieve certainty to act.

Acknowledgments

The author wishes to thank Quentin Hiernaux and Jacques Godfroid for their helpful advice and discussions. EM is a Senior Research Associate from the FRS-FNRS (Belgium).

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.endeavour.2020.100709.

[111] Thomas Hobbes, *The Leviathan* (London: Andrew Crooke, 1651), 37.

[112] Nathan Caplan, "The Two-Communities Theory and Knowledge Utilization," *The American Behavioral Scientist* 22, no. 3 (1979): 459–70, https://doi.org/10.1177/000276427902200308; Carol H. Weiss, "The Many Meanings of Research Utilization," *Public Administration Review* 39, no. 5 (1979): 426–31, https://doi.org/10.2307/3109916; Peter Scholten, "The Limitations of Policy Learning: A Constructivist Perspective on Expertise and Policy Dynamics in Dutch Migrant Integration Policies," *Policy and Society* 36, no. 2 (2017): 345–63, https://doi.org/10.1080/14494035.2017.1322263.

[113] Weiss, "The Many Meanings of Research Utilization" (ref. 115), 429.

[114] Martin Bauer, "Socio-Demographic Correlates of DK-Responses in Knowledge Surveys: Self-Attributed Ignorance of Science," *Social Science Information* 35, no. 1 (1996): 39–68, on 39, https://doi.org/10.1080/08858190209528804.

[115] Caplan, "The Two-Communities Theory and Knowledge Utilization" (ref. 115), 459, https://doi.org/10.1177/000276427902200308.