Towards a New Ethos of Science or a Reform of the Institution of Science?

Merton Revisited and the Prospects of Institutionalizing the Research Values of Openness and Mutual Responsiveness

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ABSTRACT

In this article, I will explore how the underlying research values of 'openness' and 'mutual responsiveness', which are central to open science practices, can be integrated into a new ethos of science. Firstly, I will revisit Robert Merton's early contribution to this issue, examining whether the ethos of science should be understood as a set of norms for scientists to practice 'good' science or as a set of research values as a functional requirement of the scientific system to produce knowledge, irrespective of individual adherence to these norms. Secondly, I will analyse the recent codification of scientific practice in terms of 'scientific integrity', a framework that Merton did not pursue. Based on this analysis, and illustrated on the case of COVID-19 as a case in which the institution of science was challenged to deliver urgently on societal desirable outcomes, I will argue that promoting open science and its core norms of collaboration and openness requires broader governance of the institution of science in its relationship with society at large, rather than relying solely on self-governance within the scientific community through a new ethos of science. This conclusion has implications for re-evaluating research assessments, suggesting that the evaluation of the scientific system should take precedence over evaluating individual researchers, and that incentives should be provided to encourage specific research behaviour rather than solely focusing on individual research outputs.

INTRODUCTION

Over the past decade, we have witnessed a gradual and consistent evolution of research practices towards a more open science (Miedema, 2021). This shift has been driven by both internal expectations within the scientific community and external demands from research policies. The European Commission (2014 and 2015) and the National Academies of Science (2018) started to foster open science in research policy with the expectation that open science will:

- Enhance credibility by addressing issues of scientific integrity in an open and transparent context.

- Improve reliability through early and effective data verification made possible by open science.

- Increase efficiency by preventing redundant research efforts and fostering broader collaboration.

- Meet societal demands by making science more transparent and accessible.

The push for open science within the scientific community has been further reinforced by negative trends such as slow publication processes, criticism of the peer review system, and challenges in reproducing research results (*Nature*, editorial May 2016). Moreover, the urgent need for open science outside the scientific community has been highlighted by the COVID-19 crisis, which exposed the inefficiency of the scientific system in responding timely to public concerns. Against this back-drop, I defined 'open science[1]' as the early sharing of knowledge and data in open collaboration with relevant stakeholders (von Schomberg, 2019; Burgelman *et al.*, 2019). Transitioning towards open science is essential for enabling responsible research and innovation (von Schomberg *et al.*, 2023; Owen *et al.*, 2021).

In this article, I will explore how the underlying research values of 'openness' and 'mutual responsiveness', which are central to open science practices, can be integrated into a new ethos of science. The key question to address is whe-

[1] I prefer to talk about 'open research and scholarship' which explicitly clarifies the inclusion of the social sciences and humanities. However, in policy circles the term open science is now consistently employed.

ther practicing open science necessitates a transformation of research cultures. Firstly, I will revisit Robert Merton's early contribution to this issue, examining whether the ethos of science should be understood as a set of normative guidelines for scientists to practice 'good' science or as a functional requirement of the scientific system, irrespective of individual adherence to these norms. Secondly, I will analyse the recent codification of scientific practice in terms of 'scientific integrity', a framework that Merton did not pursue. Based on this analysis, I will argue that promoting open science and its core norms of collaboration and openness requires broader governance of the institution of science in its relationship with society at large, rather than relying solely on self-governance within the scientific community through a new ethos of science. This conclusion has implications for revaluating research assessments, suggesting that the evaluation of the scientific system should take precedence over evaluating individual researchers, and that incentives should be provided to encourage specific research behaviours rather than solely focusing on individual research outputs.

MERTON REVISITED

In 1942, Robert K. Merton, one of the founders of the sociology of science, authored a short essay titled 'The Normative Structure of Science', which included a section called 'The Ethos of Science'. Merton described the ethos of science as 'that affectively toned complex of values and norms which is held to be binding on the man of science' (Merton, 1942). He introduced the CUDOS norms, consisting of communism, universalism, disinterestedness, and organized scepticism, as the institutional imperatives that comprise the 'ethos of modern science'. Here, I will specifically focus on Merton's norm of 'communism[2]', as it bears an obvious relationship to the norms of open science, such as openness and responsiveness.

[2] Many commentators of Merton's work have referred to this norm as 'communalism' because of its political-economic connotations. Communalism also appropriately refers to a community of scientists which produces communalized products. Although communalism captures Merton's intention appropriately, I will employ Merton's original wording for purely historical reasons.

In his essay, Merton (1942) characterizes communism as follows (quotations are from the paragraph on communism in Merton's 1942 essay).

- 'The substantive findings of science are a product of social collaboration and are assigned to the community'.

- Scientific knowledge is a common property. 'The institutional conception of science as part of the public domain is linked with the imperative for communication of findings. Secrecy is the antithesis of this norm; full and open communication its enactment'.

- 'Free access to scientific pursuits is a functional imperative'.

- The scientist's claim to his intellectual property is limited to that of recognition and esteem.' The institutional consequence is that scientists pursue originality and driven by a competitive quest for priority. However, 'the products of competition are communized'. It concerns a 'competitive cooperation'.

Throughout the years, scholars have debated whether the CUDOS norms represent values for the proper functioning of the scientific system (cognitive functional meaning) or normative prescriptions and moral imperatives guiding scientists' behaviour within a lived ethos (Stehr, 1978). It can be assumed that Merton himself was aware of this ambiguity since he articulated communism both as a functional imperative for the institution of science to generate shared knowledge for the public domain through competitive cooperation, and as an ethical norm governing proper scientific conduct. Additionally, Merton stated that the CUDOS norms are not exclusive to science but can be present in any social structure. There is no demarcation criterion that distinguishes science from non-science based on a specific set of norms. The CUDOS norms represent an ethos, an idealized framework for the scientific community to strive towards rather than a fully attainable reality. Merton did not intend to codify these norms and recognized that actual scientific practices may not always align with the demands of this ethos. In other words, Merton's ethos serves as a critical yardstick for assessing the behaviour of scientists. Just as Rawls appeals to political and civic virtues of citizens in his concept of the 'public use of reason' for a just and fair society (Rawls, 1993), Merton's ethos of science relies on the cultivation of scientific virtues by members of the scientific community. For our discussion, it is important to recognize that the Mertonian norms can be viewed both as values of the scientific system for its proper functioning and as prescriptions for appropriate scientific conduct within the scientific community.

EXPLICATING THE NORM OF COMMUNISM

Below, I aim to demonstrate that the norm of communism presupposes subnorms of mutual responsiveness and openness, with social collaboration among knowledge actors as a logical consequence.

Merton asserts that scientific knowledge is a result of 'full and open communication' (as quoted above). He assumes that scientific knowledge emerges through the open sharing of outputs produced by 'competitive cooperation'. However, he does not delve into how mutual understanding can be achieved within the scientific community when dealing with conflicting scientific findings, ultimately leading to a shared understanding that can reasonably become part of the public domain. While Merton explicitly considers 'openness' in the communication structure of scientists, he does not elaborate on the normative assumptions underlying this open communication structure. Merton's openness solely relates to the public sharing and communication of knowledge, even though he anticipates an eventual mutual understanding of scientists in terms of 'certified knowledge'. Merton stated: "The institutional goal of science is the extension of certified knowledge" (Merton, 1973, page 270). The American philosopher Charles Sanders Peirce revealed the inherent communicative presuppositions of scientific research practices and communication in terms of an involvement of community of interpreters (Peirce, paragraph 311), which Habermas later generalized beyond the scientific realm to communicative action (Habermas, 1996). Habermas's insight centres on the notion that any serious contender of truth or normative claims must engage in argumentative praxis, counterfactually anticipating a mutual understanding of context-transcending claims (Habermas, 1996, p.13). This implies a norm of mandatory answerability to discussion partners. In other words, members of the scientific community who aspire, counterfactually, to adhere to Merton's norm of communism and open communication must be mutually responsive to one another's insights. While Merton reduces openness to *openness to knowledge sources* such as publications arising from competitive cooperation, a comprehensive understanding of openness encompasses an *openness and mutual responsiveness to* any member of the scientific community as *a knowledge actor*.

SELF-GOVERNANCE OF SCIENCE THROUGH COMPETITIVE COOPERATION OR GOVERNANCE BY CO-RESPONSIBILITY OF KNOWLEDGE ACTORS?

Merton perceives scientific knowledge as a product of social collaboration. However, he fails to convincingly argue that knowledge generation is the outcomes of only this specific social collaboration at the aggregate level of the system of science by means of competitive cooperation with a common benefit for the scientific community. The term 'social collaboration' should be understood more broadly. Merton's concept of competitive cooperation pertains to working within a scientific community to primarily achieve individual goals as a scientist, assuming that this is the most productive approach for the scientific system as a whole. On the other hand, collaboration involves working with other members of the scientific community to produce shared research findings and achieve collective goals.

The practice of 'mutual responsiveness' not only leads to knowledge production through argumentative discourse but also enables coordinated research actions based on a shared understanding of the subject matter. This can result in interdisciplinary or transdisciplinary research missions that go beyond the boundaries of specific scientific disciplines, fostering knowledge generation in diverse settings. If a scientific community embraces and acts upon the norm of 'openness', increased mutual understanding of scientific insights and collaborative research actions based on such understanding become possible.

Merton acknowledges that social collaboration and the adoption of social norms are not unique to the scientific community but also exist in other social contexts. He acknowledges that there is no clear demarcation between science and non-science in terms of norm adoption. Similarly, we cannot distinguish science from other collaborative contexts solely based on social collaboration. Consequently, we lack a rational basis for categorically disqualifying non-scientific knowledge actors from engaging in scientific discourse, even if they may not fully comprehend the subject matter[3]. Science can be seen as an institutionalized form of scientific discourse, which might imply specialization in scientific discourses or cooperative truth-seeking processes. However, when collaborating within science, we inevitably engage in normative discourses regarding research goals and priorities.

Merton's work primarily focuses on science at the frontiers of knowledge generation, rather than science's capacity to address societal problems. He aligns himself with those who perceive direct societal intervention in science as a distortion of its nature, alluding to the 'norms of pure science' when describing the ethos of science (Storer, 1973, page ix). Merton's contribution can be seen as a sociology of science that abstracts from the contents of scientific knowledge. Thomas Kuhn's *The Structure of Scientific Revolutions* (1962) repre-

[3] S.O. Funtowicz and J. Ravetz (2015) concluded that not only the production of knowledge should be identified beyond the scientific community but that also the evaluation of the quality of knowledge needs to be conducted by an 'extended peer community'.

sents a subsequent phase in the reception of Merton's work, complementing it with a sociology that examines the contents of science and further articulating the dichotomy between cognitive and social norms of science (Stehr, 1978). While Merton explicitly denied the existence of a demarcation criterion based on norms, post-Kuhnian sociology and philosophy of science have failed to establish a conclusive cognitive demarcation criterion. Paul Feyerabend's *Against Method* (1975) ended a search for such criterion. In line with Habermas' notion of argumentative discourse and communicative action, we cannot effectively differentiate between a scientist making a truth-claim and an ordinary citizen doing the same. However, if we wish to give substantive direction to science beyond the inherent growth of knowledge pursued by 'pure' science, knowledge actors inside and outside of science must engage not only with truth-claims but also with normative claims regarding the 'right' direction for science. Therefore, forms of social collaboration among knowledge actors within and outside of science are appropriate for any democratic society. In a post-Kuhnian and post-Mertonian world, this is effectively realized through various interfaces between science and society, such as science funding bodies, science communication institutions, and technology assessment institutions (Pereira *et al.*, 2017; Grunwald 2018).

Karstenhofer (2021) examines Merton's norm of 'communism' in the context of technology assessment practices within the science-society interface and proposes an expanded concept of communism that goes beyond the boundaries of the scientific community and includes values such as 'transparency'. Social collaboration in shaping the direction of science or aligning science with research missions that produce socially relevant outcomes becomes essential due to the increasing number of societal challenges we face. Interestingly, there is neither substantial scientific evidence supporting the functional effectiveness of Mertonian norms in science, nor there has been put forth any significant proposals for a set of alternative norms post-Merton (Storer, 1973). This also applies to the recent call for open science, where initial empirical evidence supporting the claim that open science makes research more responsive to societal demands is lacking. However, the situation has changed significantly since the COVID-19 pandemic. It can be easily demonstrated that the scientific community globally engaged in collaborative efforts related to COVID-19, with millions of data submissions on open data sharing platforms established under public policy pressures (COVID-19 Data Portal, See also the recent commissioned study by Frontiers of Spichtinger on the impact of Open Science on Covid research 2024). This collaboration in open science mode was instrumental in managing the pandemic and expediting the development of effective vaccines within an accelerated period. Such collaboration cannot be fully explained by Merton's notion of competitive cooperation. While Merton suggests that social collaboration in the form of competitive cooperation enables self-governance of science at the aggregate level, the COVID-19 case clearly demonstrates that self-governance was not a viable option for research policy.

Social collaboration can take various forms. It can occur at the institutional level within the interfaces of science and society without directly interfering with the actual research process. However, it does imply a shared responsibility of societal and scientific knowledge actors in steering science and innovation. The European Union, for example, has recently initiated funding for mission-oriented research addressing societal challenges (Horizon Europe, 2021-2027). Beneficiaries of the EU funding program Horizon Europe are required to envision collaborative research and innovation actions involving knowledge actors from the Quadruple Helix, including academia, industry, civil society, and public authorities. This type of research is characterized as co-designed and co-created with stakeholders (Mazzucato *et al.*, 2020), extending the norms of 'openness' to encompass not only knowledge sources but also knowledge actors beyond academic science. The requirement for mutual responsiveness among knowledge actors within the Quadruple Helix is particularly evident in the co-creation of research agendas, potentially enabling forms of anticipatory governance and directing science towards socially desirable outcomes (Robinson *et al.*, 2021). The process of co-creation and co-design is guided by sociotechnical imaginaries. That is, as a set of visions sustained by infrastructures, practices, and more or less shared meanings of social life which in turn reveal futures that are desirable for a society (Jasanoff & Kim, 2015, p. 4, Nordmann, 2023). These imaginaries portray desirable futures for society. Societal-challenge driven mission-oriented research can even revolve around a socio-technical imaginary itself. For instance, the notion of 'smart cities' indicates what is desirable through the use of technology and social innovation and how cities should be managed (Tironi & Albarnoz, 2021). Social collaboration includes consensus-building on problem definitions and the problem-solving capacities we intend to employ. On one hand, this can neutralize scientific dissent, for the duration of the missions, which often arises due to discipline-specific approaches and implicit problem framings (von Schomberg, 1992, and 2012). On the other hand, it can overcome one-sided problem definitions prevalent in public policy settings. For example, climate change policy historically emphasized climate mitigation strategies while neglecting climate adaptation strategies (Stehr, von Storch, 2023). The latter were relegated to science funding programs and were treated as 'alibi' research, a body of research that never constitute a basis for policy advice (von Schomberg, 1992).

In an ideal scenario, knowledge actors engaged in social collaboration within mission-oriented research would share responsibility for the potential impacts and outcomes of their research. Ongoing monitoring, foresight exercises, and technological assessments can facilitate anticipation of these impacts. These aspects reflect the broader concept of scientific governance that Science and Technology Studies scholars have emphasized in their work (Irwin, 2008; Rip, 2018). Helga Nowotny (Nowotny *et al.*, 2001) has also emphasized the emergence of a context sensitive science based on an interactive and co-evolving science-society relationship.

Therefore, we can conclude from the review of Merton's work that a comprehensive governance of science takes shape through various forms of social collaboration, extending beyond Merton's notion of competitive cooperation. Knowledge actors collectively share responsibility for the anticipated outcomes of research actions.

In summary:

- The research norm of 'openness' should encompass both knowledge sources and knowledge actors.

- 'Openness' needs to be further defined in terms of 'mutual responsiveness' among knowledge actors.

- There are no clear demarcation criteria for distinguishing knowledge actors within and outside of science.

- Social collaboration requires mutual responsiveness to the normative framing of research goals, thereby providing substantive direction to science beyond the mere growth of knowledge.

- Science governance involves a wide range of knowledge actors engaging in social collaborations with scientists to achieve desirable societal outcomes.

- The case of 'open science' during the COVID-19 pandemic illustrates that self-governance of science was not a viable option for research policy.

These observations highlight the importance of social collaboration and co-responsibility among knowledge actors to steer science towards addressing societal challenges and achieving desirable outcomes.

SELF-GOVERNANCE OF THE INSTITUTION OF SCIENCE VS SELF-GOVERNANCE BY AN ETHOS OF SCIENCE

Merton's assertion that the four norms of science are not exclusive to science is valid. He emphasized the significance of cultural norms, particularly the role of a Protestant ethic (Merton, 1973, p. 228). The interconnectedness of specific norms within society and the scientific community is relevant. Schendzielorz *et al.* (2021) also connect the scientific ethos with the democratic ethos and conclude that the Mertonian norms are best understood as a set of procedural norms for self-governance. However, Merton (1973, p. 273) argued that science can be better *fostered* in an open, democratic society than in other types of societies. The norm of civic participation in a 'democracy' is a lived ideal for citizens, just as the norm of 'communism' is a lived ideal for the scientific community. Both norms presuppose the value of 'openness'.

This highlights 'openness' not as a prescriptive norm but as a value of the institution of science. Simultaneously, 'openness' is also an institutional value of a democracy. If we primarily understand the norm of communism as an institutional value of science, then communism and openness become research virtues for the scientific community rather than prescriptive norms. Similarly, 'voting' is considered a civic virtue in a democracy, even though the institution of democracy does not oblige individuals to vote. This line of thinking aligns with Merton's rejection of codifying the four norms, which can be seen as functional for the operation of science and therefore represent institutional values. In this way, we can understand Merton's formulation as a self-governance of the institution of science through the adoption of appropriate research virtues by the scientific community.

In a post-Mertonian world, after lengthy discussions among academies of science, norms of 'good' scientific conduct have been codified. For a long time, academies of science and funding organizations primarily phrased these norms in negative terms, focusing on what constitutes misconduct in science. For example, the US Office of Research Integrity (ORI) defines research misconduct as 'fabrication, falsification, or plagiarism in proposing, performing, or reviewing research, or in reporting research results'. Eventually, the All-European Academies adopted a set of codified principles of research integrity and incorporated them into the European Code of Conduct for Research Integrity (ALLEA build on and extended the principles and responsibilities set out in the 2010 Singapore Statement on Research Integrity which represented the *first* international effort to encourage the development of unified policies, guidelines, and codes of conduct world-wide (Singapore Statement on Research Integrity). Since 2017, the European Commission has recognized the ALLEA Code as the reference document for research integrity in all EU-funded research projects and as a model for organizations and researchers.

It is worth noting that none of the CUDOS norms have been included in a code of conduct for researchers. In fact, the code of conduct primarily appeals to normative principles of *honesty, reliability, accountability, and respect*, with a focus on the quality of scientists' publishing behaviour rather than their actual work in their research fields. This focus on misconduct in publishing arose due to the increasing importance of publications for research careers and funding. Furthermore, the scope of codification is limited to matters of scientific integrity, even though these norms or principles have been described as fundamental to 'good' research practices. The responsibility of the scientific community is described as an overarching duty to 'promote, manage, and monitor a research culture based on the scientific integrity of its members'. (ALLEA, 2023). The implementation of scientific integrity is managed through *self-regulation by the scientific community*. This contrasts with Merton's conception of self-governance of the institution of science in which self-governance of science is achieved by a scientific community appealing to the *institutional values of science* by scientists adopting scientific virtues.

SELF-GOVERNANCE OF SCIENCE AND EXTERNALIZING ISSUES OF RESPONSIBILITY

The scientific community, represented by the Academy of Sciences, has been more reactive than proactive in formulating a set of norms for scientific integrity. Only in 2017 did they adjust an original draft of the code to address challenges arising from technological developments, open science, and citizen science. It is important to note that the value of 'openness' was added to the code subsequent to the rise of open science and citizen science. However, compared to Merton's 1942 demand for 'full and open communication', the 2017 Code is still relatively weak on open science. The European Code instead states among other: 'researchers (…) ensure access to data is as *open as possible*, as closed as necessary' and 'All partners in research collaborations agree at the outset on the goals of the research and on the process for communicating their research as transparently and *openly as possible*'.

Merton rejected Intellectual Property Rights (IPR) in research practices as a violation of 'communism' and incompatible with the integrity of the knowledge production process, a concern not echoed by ALLEA. Merton believed that knowledge generation is a common good, and the privatization of knowledge was critically viewed even in the 1940s, though it was less prevalent than today. Merton argued that personal esteem and recognition for scientific ideas should be the primary driving force. Only personal esteem and recognition for having originally proposed successful scientific ideas is what should matter and drive scientists in a competitive cooperation for a quest of priority. According to Merton, there is no better recognition and reward for a scientist than being named after a discovery, such as *Newtons* gravity laws.

Furthermore, it is worth noting that the scientific community only agreed on codes of conduct as tools for self-governance due to external pressure from science policy, science funders, and societal demands. The scientific community did not initiate the initiatives to codify scientific practice themselves. The community has long feared losing control over its own governance to societal interference, leading to a delayed and limited response to 'open science' after it was already adopted a formal public policy (European Commission, 2015). In a case of less public attention, the scientific community did not wish to give any substantial follow-up to regulatory measures such as the European Commission's recommendation to adopt a code of conduct for responsible nano sciences and nanotechnologies research (2008), a code which stated social responsibilities for among other human health, environmental safety, and human rights, going far beyond matters of research integrity.

Merton was equally worried about of a form of 'responsibility' science should not get burdened with. But he argued for this position more consistently than the Academies of Sciences, who stand in his tradition, currently do. ALLEA silently embraces a broad set of IPR within the research context while rejecting any responsibility for the social outcomes and impacts of science and technology. Merton, on the other hand, argued against holding science responsible for outcomes it could not foresee or prevent. He advocated for a 'pure' science whose primary function is knowledge growth, regardless of whether the resulting knowledge proves beneficial to society. In an IPR-free research context driven solely by scientists' pursuit of recognition and esteem, the integrity of the scientific system would be guaranteed.

He commented on the fear in the 1940s that new technologies would cause a loss of jobs and the broad public concern with the negative outcomes of technological advance as follows (italics are mine):

> 'Precisely because scientific research is not conducted in a social vacuum, its effects ramify into other spheres of value and interest. Insofar as these effects are deemed socially undesirable, science is *charged with responsibility*. The goods of science are no longer considered an unqualified blessing. Examined from this perspective, the tenet of pure science and disinterestedness has helped to prepare its own epitaph. Battle lines are drawn in terms of the question: can a good tree bring forth evil fruit? Those who would cut down or stunt the tree of knowledge because of its accursed fruit are met with the claim that the evil fruit has been grafted on the good tree by the agents of state and economy'. (Merton, 1973, p. 263)

The state of science in 2023 is different. The sciences have evolved over the decades post-Merton and are now intertwined with societal and industrial interests. Merton's image of science as primarily aimed at explaining or understanding natural and social phenomena has been subject to change, with many sciences adopting an engineering perspective. Biology, for example, now includes engineering practices that were unimaginable during Merton's time. Graig Venter brought this to a point in an impressive keynote lecture on the question 'What is Life' at a ESOF conference in Dublin (Venter, 2012). His answer: 'I will understand it when I can create it'. Hence his preoccupation with engineering a synthetic self-replicating living cell. The engineering perspective has permeated almost all natural sciences, resulting in outcomes that are increasingly a matter of creation and design. We now even anticipate the social and physical consequences of technological products and use phrases like 'safety by design' (nanoscience) and 'privacy by design' (computer sciences). This engineering perspective brings the issue of responsibility internally to science itself, as the ability to create or design implies responsibility for the outcomes. The traditional full 'externalization' of responsibility for the outcomes of the science to politics and the economy as Merton suggested is nowadays untenable from the perspective of a *responsible* engineer. This is also echoed in the history of various codes of conducts, national and scholarly societies of engineers have adopted over time. These codes, in contrast with the code of the Academies of Sciences, have not refrained from adopting social responsibilities, including addressing the safety and welfare of the public and, most recently, adopting principles of sustainable development (for a comprehensive overview, see Mitcham (2020), chapter 16).

This shift towards engineering practices within the sciences has resulted in a less engagement with the research value of 'openness'. Engineering sciences often produce inventions rather than scientific discoveries, and inventions are closely associated with intellectual property practices, as only inventions can be patented, not scientific discoveries. The engineering perspective integrates better understanding of natural phenomena with creations and inventions.

For example, Nobel Prize winner Feringa's construction of a molecular-driven 'nano car' demonstrates the connection between inventions and a better understanding of natural laws:

> 'The driving force behind the project was the desire to *figure out* how to get an entirely synthetic, single-molecule system to move on its own across a surface' (…) Probably future *designs* will be different from what we show here, but we have to *demonstrate the fundamental principles*. (Citation of Feringa in *Chemical and Engineering News*, 2011).

In a similar vein, Graig Venter has 'figured out' how a better understanding of biology contributed to the creation of a self-replicating synthetic bacterial cell. Graig Venter has filed dozens of patents for his 'inventions' including the generation of synthetic genomes. (Venter, the Patents of Graig Venter). The increasing specialization within the sciences and the rise of engineering have introduced issues of responsibility explicitly into the sciences, particularly in terms of responsibility for designs. Consequently, this implies a decrease in the importance of 'openness' for the functioning of the system of science. Mitroff (1974) formulated on the study of Apollo moon scientists Mertonian counter norms, e.g., particularism, secrecy, organized dogmatism, and selfinterestedness. Instead of focusing on knowledge generation and sharing, engineers lay a greater emphasis on knowledge mobilization and acquisition to create things like nano cars or synthetic cells. This shift reflects a departure from Merton's concept of pure sciences.

However, we can view engineering sciences as a form of science, which relies on, and benefits from sciences that aim primarily to enhance our understanding of natural and social phenomena. Therefore, the engineering sciences are beneficiaries of a scientific system that strives to be as open as possible[4]. With the emergence of 'open science,' there is also a contrasting trend to the trend of the uptake of an engineering perspective, namely the emergence of interdisciplinary sciences benefiting or even basing itself on an open science rationale. Climate scientists, for example, seem to operate to a significant extent on the basis of an open science rationale of open data sharing. In this case, empirical research has demonstrated that climate scientists are still ethically guided by Mertonian norms, but the current system of science incentives them to deviate from these norms with, among other, 'a tendency to withhold results until publication and the intention of maintaining property rights (Bray & von Storch, 2017). Paradoxically, these relative open science interdisciplinary research practices have emerged against the background of an ever-increasing specialization and proliferation of disciplinary approaches in the sciences post-Merton, based on specific epistemic cultures and specific paradigms. These scientists see themselves predominantly as members of a scientific discipline rather than the scientific community as such. 'Openness' becomes then at best a virtue of a scientific discipline. Karin Knorr-Cetina's anthropology on epistemic cultures (1999) even put in question the unity of the sciences.

[4] I cannot extensively deal here with the notion of open innovation, which also effects the engineering sciences despite their ambivalence towards openness. In parallel to Open Science, Open innovation is essentially based on the innovation as a collaborative networked activity. Benkler (2017) adequately summarizes and captures the various shifts towards open innovation practices whereby innovation is primarily an emergent property of knowledge flows, sharing, and collective learning in communities of practice and knowledge networks rather than a result of traditional individual and firm-based innovations. Benkler (2017) also notes a shift from pure market-driven innovations to innovations that are driven by social motivations and public investment.

TOWARDS A NEW ETHOS OF THE SCIENTIFIC COMMUNITY OR AN INSTITUTIONAL REFORM OF SCIENCE?

In light of these considerations, the question arises: should we focus on self-governance of the scientific community through a set of prescribed norms or on the self-governance of the institution of science through a set of institutional values? Theoretical discussions on this matter may not yield a conclusive answer. However, empirical evidence dismisses the notion of self-governance by either the scientific community or the institution of science.

Firstly, it is evident that science governance is influenced by a wide range of knowledge actors who engage in social collaborations with scientists to achieve desirable societal outcomes. This collaboration entails the civic virtue of openness and demands for the participation of knowledge actors in a democracy, aligning with the virtues of openness to diverse knowledge sources in science. It also signifies the willingness of actors to share responsibility for the anticipated outcomes of research and innovation. Secondly, the issue of responsibility has not only been raised by external knowledge actors but also by the sciences themselves, which are increasingly dominated by an engineering perspective. Instead of adhering to the Mertonian norm of 'disinterestedness', scientists and engineers advocate their work in terms of its potential societal impact, for example, by taking on '14 game-changing goals for improving life on the planet', ranging from 'advancing personalized medicine to reverse-engineering the human brain and addressing cross-cutting themes of sustainability and joy of life' (Venter, Engineering Challenges). Constraining the issue of responsibility solely to science-internal codified norms of scientific integrity or to competitive cooperation among knowledge actors for knowledge growth, as proposed by Merton, contradicts the empirical reality of the 21st century. In practice, we are evolving towards a system of co-responsibility through social collaboration between scientists and external knowledge actors, as well as steering science in the desired direction through science-society interfaces, including science funders, charitable organizations like the Gates Foundation and technology assessment offices.

THE CO-RESPONSIBILTY OF SCIENCE GOVERNING ORGANIZATIONS

Having settled the issue of self-governance in favour of co-responsibility between knowledge actors and science governing bodies at the science-society interface, we still face the question on how we could now ensure that our extended notion of 'communism' in terms of openness and mutual responsiveness can be adopted by either the institution of science as a set of values, or by an extended ethos of science of the scientific community. Consistent with our analysis, any such a change has to come from the science-society interface. Research funders will have here a responsibility as they co-define the rewards and incentives system together with the employers of scientists. As science funders occupy a significant role as co-responsible actors at the science-society interface, they must consider how to promote open science if that is the type of science they wish to foster. To address this question, I will first examine the evolving practice of open science before returning to the conceptual level.

During the largest Ebola outbreak in history, a group of international researchers sequenced three viral genomes from patients in Guinea. The data was made public that same month, and this open scientific practice facilitated the availability of experimental vaccines within a short period. This approach proved vital in combating relatively smaller outbreaks in 2018.

The case of Ebola demonstrates that when faced with a public health emergency, it is crucial not to rely solely on the moral initiative of a few researchers. The institution of science demonstrated a system-failure by its inability to respond timely to urgent societal demands. The conventional process of publishing articles and patenting vaccines is inadequate in such situations. I have previously discussed how this system-failure is associated with both a productivity crisis and a reproducibility crisis in the sciences[5] (von Schomberg, 2019).

Science governing organizations initially responded to emerging public health issues such as Ebola and Zika by addressing the system failure within science in a limited manner. For example, the National Institutes of Health in the United States began requiring grantees to make large-scale genomic data publicly available no later than the time of publication. The World Health Organization (WHO, 2015) advocated for a paradigm shift in information sharing during public health emergencies, moving away from embargoes and toward open sharing using suitable pre-publication platforms. The WHO recognized that patents on natural genome sequences could inhibit further research and product development, urging research entities to exercise discretion in patenting and licensing genome-related inventions to avoid hindering progress and to ensure equitable benefit sharing. The organization also called on scientific publishers to encourage or mandate the public sharing of relevant data rather than penalizing it. However, it was not until the COVID-19 pandemic that science funders, publishers, and industries took more rigorous steps toward open science under pressure from public authorities and funding institutions.

The system-failure of the institution of science to deliver timely on socially desirable outputs, such as vaccines, underscores the need to move beyond relying solely on the moral initiative of a restricted group of researchers. We can not just simply extend Mertonian norms with an extended set of codified norms which included *norms* for 'openness' and 'mutual responsiveness.' Therefore, a reform of the institution of science is

[5] The 'reproducibility' crisis (in which scientists have increasingly difficulties to reproduce the research findings of their colleagues) comes together with a 'productivity' crisis which are linked to an increasingly competitive closed science. Research efforts (in terms of financial investments) have increased exponentially during decades whereas research productivity has dropped dramatically. Bloom *et al.* (2020) found that 'since the1930s, research effort has risen by a factor of 23 — an average growth rate of 4.3 percent per year'. However, research productivity (in terms of economically viable and socially desirable innovations) has fallen: 'by a factor of 41 (or at an average growth rate of -5.1 percent per year') (Bloom *et al.*, 2020, p. 7).

due which aims at an institutionalization of the *values* of openness and mutual responsiveness, by an overhaul of the rewards and incentives system. To put it in a simplified form: if scientists are rewarded and incentivized to do the 'right' thing, then the majority of the scientist will most likely do so independent whether they appreciate particular Mertonian norms or whether they remain full skeptical about adopting any form of ethics. A new incentives system that rewards scientists who work in an open and collaborative mode will institutionalize the values of 'openness' and 'mutual responsiveness' for a better functioning of the scientific system. The shift from a closed form of science to open science is a necessity for enabling the institution of science to respond timely, not only to emerging public health issues, but to all urgent societal challenges. Co-responsibility of science-society interfaces for science governance implies institutional aspects and a change in the science-society relationship (see also Bijker *et al.*, 2022) who have advised on among other, how the value of 'openness' for responsible biosciences could be considered in the framework of a revised science-society contract). I have elaborated elsewhere that rewarding open science implies a shift from primarily rewarding scientific outputs such as publications to rewarding research behavior such as knowledge and data sharing and social collaboration prior to publishing (von Schomberg, 2023).

The European Commission thus took the right decision to initiate a reform of the institution of science rather than focusing on a new ethos of science (European Commission, 2015). It was only in January 2022, after extensive preparatory work by the European Commission, that a coalition of over 350 organizations from more than 40 countries, including public and private research funders, universities, research centers, institutes, and university associations, eventually agreed to *initiate* a reform process (CoARA) (which builds on, among other, the 2012 self-regulatory initiative of individual researchers and research governing organization: the

San Francisco Declaration on Research Assessment, DORA, 2012). The intention is to transition to a research assessment system that emphasizes a qualitative approach within the framework of traditional peer review. However, it remains to be seen if institutions are willing to significantly shift from a system that primarily rewards research outputs to one that rewards research behaviour. Institutions often hide behind the cherished 'autonomy' of universities and research institutions, claiming a Mertonian heritage of pure science that no longer exists.

Based on our review of Merton's legacy, we can now propose a reformulation of the science-society relationship, emphasizing the co-responsibility of knowledge actors as knowledge co-producers and the involvement of a broad range of science governing institutions at the science-society interface. Merton stated, 'The scientist came to regard himself as independent of society and to consider science as a self-validating enterprise which was in society but not of it' (Merton, 1973, p. 268).

Building upon our review, I propose the following rephrasing: The scientists came to regard themselves as knowledge co-producers and consider science as a co-validating enterprise that is in society and with it. Furthermore, Merton stated, 'When the institution of science operates effectively, the augmenting of knowledge and the augmenting of personal fame go hand in hand' (Merton, 1973, p. 323). In light of our analysis, we can conclude that 'when the institution of science operates effectively, the augmentation of knowledge and its relevance for addressing societal challenges go hand in hand'.

OUTLOOK AND DISCUSSION

The COVID-19 pandemic has greatly accelerated the adoption of open science practices, which now permeate all stages of the research process. Open science entails the active involvement of all relevant knowledge actors, fostering co-production from research agenda setting to scientific discovery and analysis. Among other, the utilization of open notebooks enables real-time data sharing, while open peer-review and knowledge dissemination promote wider outreach (von Schomberg 2019, Burgelman *et al.*, 2019, Miedema, 2021).

A radical open science practice entails an unprecedented level of openness that could not have been conceived by Merton in 1942. As noted by Hosseini *et al.* (2021), this openness encompasses not only knowledge but also various data and code and allows for real-time communication rather than waiting until the point of publication. Consequently, the traditional Mertonian incentives system, which emphasizes the 'quest for priority', becomes inapplicable to a radical open science practice. The Covid-19 pandemic has highlighted the importance of early information sharing among researchers, implicating a loss of originality at the time of publication. Consequently, I propose a shift in the rewards and incentives system, moving beyond solely focusing on research products like publications, to considering research behavior that aligns with research missions, such as collaboration and mutual responsiveness among knowledge actors. This new system would incentivize research institutions, such as universities, based on their contributions to collaborative research missions, thereby enhancing the productivity of the scientific enterprise. The function of the institution of science is not to deliver 'certified knowledge' as defined by Merton's 'pure' sciences but should encompass the generation of knowledge that addresses societal challenges, produced by a post-normal science characterized by significant scientific uncertainty and epistemic dissent (Ravetz & Funtowicz, 1993). Currently, the emphasis on individual researchers maximizing research outputs, such as publications, paradoxically hampers the overall productivity and responsiveness of the scientific community in tackling societal challenges. The prevailing irrational competition among universities to lead in terms of publication numbers and venues is reflected in a multitude of university rankings. While these rankings receive little public intellectual support, universities proudly promote their scores.

It is crucial to acknowledge that the current prevailing understanding and implementation of 'open science' by publishers, universities, and research policies do not align with comprehensive open science practices. Instead, the focus often narrows to the realm of 'open access' for publications and data. The open access policies currently being incrementally implemented by major scientific publishers, encouraged by research funders, can be viewed as mere adjustments to their business models.

The prevailing 'gold open access model,' favored by wealthier nations, relies on an author-pay system, effectively creating a situation where only scientists financially supported by their institutions can afford to publish in leading journals. Consequently, this may lead to a scenario where scientists prioritize to work for institutions that provide support for their publications. However, this publishing model contradicts the open science practice of sharing knowledge prior to publication. A notable example of such pre-publication sharing was already observed during the Human Genome Project, where data on the human genome was widely disseminated among the scientific community throughout the project, while there was a temporarily moratorium on publishing to encourage optimal collaboration, rather than competition.

Research conducted by Cole *et al.* (2023) has demonstrated that the unequal access to resources resulting from the current predominant open access publishing model confers distinct advantages upon certain scientists, thereby perpetuating inequities in the system that genuine open science practices aimed to eliminate. Furthermore, it restricts the ability of non-scientific knowledge actors to publish in scientific journals, creating a new form of exclusivity. Open access publishing, often accompanied by promises of higher citation rates, reinforces the traditional emphasis on individual productivity within the scientific community, rather than fostering the overall functioning of the scientific institution through collaborative efforts to address societal challenges.

Research assessments that reward research productivity based on the number of publications and citation rates further reinforce a limited understanding of 'openness,' reducing it primarily to publications. This type of 'open science' violates the Mertonian norm of communism and our extended interpretation of it, which emphasizes openness and mutual responsiveness to both knowledge sources and knowledge actors.

In table 1, I have summarized the positions attributed to Merton, the current state of affairs and the author of the article.

Table 1. Positions attributed to Merton, the current state of affairs and the author of the article.

	Merton	Current State of Affairs	Author of the article
Normative structure of the Scientific community	Ethos of Science-CUDOS norms	Research Integrity IPR regimes for entrepreneurial science	Research behavior: social collaboration and knowledge sharing, comprehensive open science rationale
Normative Structure of the Institution of Science	Institutional values cultivated by Scientific virtues	Financial framework for macro-economic benefits- aligned with national innovation systems	Institutional values including openness and mutual responsiveness, cultivated by scientific virtues of open science
Governance of the Scientific Community	Self-governance by ethos of science	Code of conduct for research integrity	Social collaboration in co-responsibility mode among knowledge actors
Governance of the Institution of Science	Competitive collaboration/quest of priority	Competitive 'research excellence' funding. Commodification of Science by Industry	Science-Society interfaces to provide direction to research and innovation
Function of the Scientific Community	Augmentation/growth of knowledge	Scientific discipline-based production of knowledge	Research missions addressing societal challenges
Function of the Institution of Science	Certified knowledge	Knowledge generation with view on societal and economic benefits	Societal Challenge based knowledge generation
Rewards and Incentives System	Originality as sole driver. Establishment of recognition and esteem in the scientific community of individual researchers	Quantitative and qualitative Productivity and Quality metrics of individual researchers	Relative contribution to research missions of research Institutions. Promotion of research behaviour: knowledge and data sharing, social collaboration among knowledge actors

Source: elaborated by the author (von Schomberg, 2024).

A topic that warrants further investigation is the potential mutual reinforcing dynamics between openness and mutual responsiveness as institutional values within both the spheres of science and democracy. My hypothesis is that social collaboration at the intersection of science and society enhances the quality of societal problem-solving capacities and facilitates the generation of knowledge for addressing societal challenges. This characteristic might be essential for a deliberative democracy seeking to revamp its governance models while confronting new challenges.

Responsible research and innovation (RRI) have emerged as a response to governance deficits in science and technology. RRI calls for a form of governance that directs science towards socially desirable outcomes or manages innovation processes to increase the likelihood of such outcomes. (Stillgoe *et al.*, 2013; Macnaghten 2020; Owen *et al.*, 2021). This approach encompasses credible research (through codes of conduct and standards for scientific integrity), responsive research (by a shift to open science and engaging with societal demands), and responsible research (including the anticipation of socially desirable outcomes by integrating foresight and technology assessment within research missions). Similar principles apply to credible, responsive, and responsible innovation (von Schomberg, 2019).

Despite the growing recognition of RRI, there are still limitations in our capacity to implement its ambitions. Research funders, such as the European Commission, have taken steps to support mission-oriented research that tackles societal challenges, enabling knowledge actors from various domains to share co-responsibility in social collaborations and anticipate socially desirable outcomes. The White House has also recently introduced measures to promote responsible AI innovation (WH, 2023). However, for these initiatives to have a meaningful impact, it is crucial to establish a rewards and incentives system that makes open science, with its core principles of openness and mutual responsiveness, the norm rather than the exception. Instituting such an institutional reform is a necessary condition for effectively implementing responsible research and innovation.

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