From "More Innovation" to "Better Innovation"?

SEBASTIAN M. PFOTENHAUER
TECHNICAL UNIVERSITY OF MUNICH
GERMANY

Abstract

This paper departs from the observation that there seems to be a new appetite for critique and reflexivity in innovation policy and innovation studies (IS), owed in part to an abundance of recent innovation controversies. In what follows, I offer a cautiously optimistic take on what this new appetite means for STS's relationship with mainstream innovation settings and why STS knowledge seems to be particularly *en vogue* right now. I explore three basic STS messages that have gained wider traction in mainstream innovation circles and that many actors not trained in STS now readily embrace: on the politics of technology, the politics of experimentation, and the work needed to situate innovation practices locally. Whether or not this new appetite for STS remains, as it were, primarily instrumental, it nevertheless opens up new opportunities for wider critical engagement and impact, and perhaps a stronger institutionalization of the field of STS.

Keywords

innovation studies; sts; policy; inclusion; controversy

Introduction

In 2019, the OECD released an official "Recommendation for Responsible Innovation in Neurotechnology," ratified by its 38 member states (OECD 2019). The recommendation provided guidelines on how governments, firms and research institutions could ensure better innovation outcomes by proactively addressing social concerns and the potential downsides of innovation early on. The document was remarkable perhaps less for the originality of its content—after all, the notion of "responsible innovation" had been around for close to a decade and high-level responsibility guidelines are being released by the dozens every year—than for the institutional context in which it was published and the kind of institutional impact it represented (Frahm et al. 2021): The OECD is arguably *the* world's principal platform for innovation policy that usually exhibits an unapologetic pro-innovation bias with a strong econo-centric orientation. It is a place synonymous with the proliferation of innovation metrics and competition among "national innovation systems," closely aligned with the academic community of innovation studies (IS). In this sense, the 2019 recommendation represents a significant departure from conventional OECD innovation wisdom.

The release of the recommendation speaks to a broader ongoing paradigm shift in innovation policy that those of us more actively involved in such settings may attest to: instead of simply asking for *ever-more* innovation (Pfotenhauer et al. 2019), many innovation actors seem to be asking for *better* innovation, embracing a more nuanced understanding of the relationship between innovation and the public good than mere economic benefits. This nuance includes aspirations to better account for how the benefits and burdens of innovation are being distributed, which "direction" innovation takes, and what kind of future is enabled (or prevented) through innovation. Indeed, the OECD episode could be seen as evidence for STS insights and tools being picked-up in mainstream innovation settings (Frahm 2022).

This policy shift is paralleled by a corollary shift in the relationship between fields of innovation studies (IS) and science and technology studies (STS). At the risk of oversimplifying, IS and STS traditionally tend to split along the lines of embracing versus problematizing innovation (Irwin 2023; Joly et al. 2010; Martin et al. 2012; Pfotenhauer and Juhl 2017). For IS scholars, the pursuit of innovation is generally seen as self-evidently desirable and the mechanics of innovation are relatively well understood and follow universal rules and rationales everywhere, even if national innovation systems differ in their designs. In contrast, STS scholars tend to treat innovation as a plurality of locally-grounded practices of social change and a powerful discourse that often favors one vision of social change and set of actors over others. STS has traditionally criticized the pro-innovation bias of IS; conversely, IS has criticized STS for merely deconstructing and throwing out the benefits of the "innovation baby with the constructivist bathwater." The boundary between these two fields has always been porous and, as shown by boundary-spanning scholars like Michel Callon, Alan Irwin, Pierre-Benoît Joly, Stefan Kuhlmann, and Arie Rip, highly generative—even with plenty of demarcation work going on elsewhere.

In the following reflections, I wish to take a closer look at this new appetite for STS insights (broadly speaking) in innovation policy and IS. To that end, I will interrogate three rather basic STS points that have made considerable headway into pro-innovation settings: first, that technologies are always political and, as a result, we should rethink innovation processes; second, that experimental introductions of new technologies are always also experiments with social and political order; third, that innovation practices and policies need to be socio-culturally situated if they ought to stick. I focus on these points because all three have been explicitly featured in recent papers in *Research Policy*, IS's flagship journal, which suggests that the IS community finds these STS messages useful and hence the relationship between IS and STS might be changing. I will illustrate each of these messages with a prominent innovation controversy from 2018—not because there is something special about 2018, but to showcase the abundance of recent examples that people can easily relate to and that even the most staunchly pro-innovation environments need to address. For seasoned STS scholars, none of these messages and examples will be surprising or shocking. But they might provide some clues for why STS is more *en vogue* today in pro-innovation settings and how to frame STS insights in ways that can help change these settings—if we indeed believe, as I do, that this what the field should strive for.

Techlash and Responsibilization as the New Normal?

In March 2018, several news outlets broke the story that the British consulting firm Cambridge Analytica had obtained user profile data of 87 million Facebook® users. The scandal that unfolded over the subsequent months brought together diverse storylines, including the habitual large-scale privacy breaches at Facebook® and elsewhere, the dark side of the surveillance-driven business models of "Big Tech," the role of micro-targeting and foreign election meddling in Donald Trump's ascent to the US presidency, and the vulnerabilities of our democracies to echo chambers.

One interesting feature of the Facebook®-Cambridge Analytica (FCA) scandal is the degree to which it continues to be seen as a story about innovation—that is, about the unforeseen problems accompanying new technologies and Silicon Valley's entrepreneurial fortunes—not just about business malpractice or questionable political motives. To many, FCA serves as a shorthand for the socially disruptive power of rapid technological change, the subversive power of algorithms and data in the digital age, and the downsides of a Silicon Valley-driven political economy of innovation where start-ups can grow from university dormitories to global behemoths in just a few years. In fact, the FCA story might resonate so widely *precisely because* it is seen as representative of innovation dynamics at large and our frustrating familiarity with innovation "scandals"—not the particularities of FCA itself.

These scandals have undoubtedly left their mark on the innovation landscape, feeding into growing sense that what is being designed in R&D labs and tech start-ups is indeed deeply political and hence able to produce both massive public backlash and a sense of helplessness. Actors are scrambling to avoid "becoming the next Facebook®" in terms of negative publicity, which has emerged as a common trope in start-up circles and innovation environments at large. Many funding bodies—including the OECD, the European Commission, the UK Research Councils ([Frahm et al. 2021](#); [Owen et al. 2021](#))—have developed specific funding lines to foster greater responsibility in innovation. In some funding programs, responsibility components have become obligatory (a trend that dates back to the mandatory ELSI components in the Human Genome Project, see e.g., [Hilgartner et al. 2017](#)). In the private sector, firms are going to increasing lengths to avoid Facebook®'s fate of constant controversy, for example by launching ethics councils or oversight boards ([Pfotenhauer et al. 2021](#)). On the scholarly side, "responsible research and innovation" (RRI) has grown into a flourishing field of research. One of the foundational papers on RRI remains among the most cited articles of *Research Policy* ever ([Stilgoe et al. 2013](#)).

For many STS scholars, this sudden interest in "responsibilization" is deeply ambivalent. On the one hand, the underlying sensitivities resonate with long-standing concerns of the field around the politics of technology, design ethics, and the Collingridge Dilemma. To many, responsible innovation seems like old wine in new bottles, partly re-packing well-known insights from public understanding of science research, anticipatory governance, or constructive technology assessment. Too often, the interest seems fleeting and instrumental, aimed at toolkits and quick fixes rather than sustained openness and necessary politicization ([Frahm et al. 2021](#); [Stirling 2008](#)). Similar to bioethics ([Hurlbut 2017](#)), the responsibilization debate might be at risk of devolving into mere box-ticking for funding requirements.

At the same time, the surge in responsible innovation talk has undoubtedly created a range of new openings for STS engagement. At my own technical university home, for instance, our STS Department is receiving more requests for collaboration from engineering colleagues to help address responsibility questions than we can handle. To the extent that I can judge, even in a decidedly pro-innovation context like ours, critical and reflexive studies of science and innovation require significantly less justification than five years ago. What is more, for all the superficial responsibility buzz, many of these initiatives are making modest but substantive headway into normalizing political conversations around technology design in places where they matter. They allow STS scholars to claim a "seat at the table" with a taken-for-grantedness that matches that of our engineering colleagues. But they do require a predisposition to collaboration and lasting involvement rather than mere outside critique, which STS has variably embraced or distanced itself from (Niewöhner 2016; Rabinow and Bennett 2012). They also require a willingness to invest oneself in, and care for, communities that might seem alien if not outright hostile, and to contribute to normative design choices if needed. As scholars, these choices can be deeply personal and tangled with broader perennial questions about STS' identity as a field.

Experimenting *in*, *with*, or *on* Society?

In March 2018, an autonomous vehicle (AV) fatally hit a pedestrian in Tempe, Arizona. For the AV's owner, the ride hailing company Uber, the accident was just the latest in a string of PR disasters that also included regular protests by taxi drivers against socio-economic dislocations, the creation of a new class of precarious labor, a toxic company culture, and regional bans of its AV testing activities. The AV accident partly resonates with the responsibility concerns discussed above. But it also connects innovation policy more explicitly to questions of experimentation, urban transformation, populations, and the imagined scale-up dynamics of innovation (Pfotenhauer et al., 2021).

Uber®'s AV testing is representative of a broader wave of "living labs" currently sweeping across the globe. In a nutshell, living labs are usually understood as designated experimental spaces where potentially transformative technologies can be tested and developed under supposed real-world conditions, and with the aspiration to spark wider systemic change. They frequently dovetail with a local reduction of regulatory constraints in the name of technological and economic benefits, and the occasional promise of more inclusive, "co-creative" approaches to innovation (Engels et al. 2019; Laurent et al. 2021).

For STS, laboratories and experiments are analytic home turf, of course. Scholars have interrogated, for example, the privileged role of laboratory spaces for the creation of authoritative knowledge (Knorr-Cetina 1995; Latour 1983); the role of public witnessing in building alliances (Shapin and Schaffer 1985); the performative staging of tests and negotiations about criteria of success and failure (Pinch 1993); the ambivalent role of field experiments as truth spots (Gieryn 2006); and the world as a laboratory for an emergent risk society (Beck 1992). However, these STS insights have traditionally not made substantial inroads into innovation policy debates.

This seems to be changing. Public experiments are proliferating and with them their visibly problematic premises and consequences. Many newspaper articles are foregrounding how for current living labs, questions of risk, regulation, and consent in these experiments are often thoroughly unresolved (Engels et al. 2019). What is more, living labs have been criticized for creating material path dependencies in favor of certain (often corporate) actors and with differential socio-economic effects, as seen in the notorious Sidewalk Labs example (Laurent et al. 2021). STS scholarship has been responsive to these concerns and has offered pertinent insights on, for example: the role of exceptions and technological experimentation for contemporary democracies (Engels et al. 2019; Laurent 2017); the durability and politicization of experimental attachments (Marres 2020; Tennant and Stilgoe 2021); the precautionary and tentative governance of emerging technologies (Kuhlmann et al. 2019; Winickoff and Pfotenhauer 2018); or the scale dynamics of technoscientific capitalism (Birch and Cochrane 2022; Laurent et al. 2021; Pfotenhauer et al., 2021).

All of these works raise important questions about who stands to benefit from the proliferation of experiments, who authorizes them, on whom, based on whose norms and values, and with what future society in mind. Yet, many of these works were developed as part of collaborative projects with engineers or policy-makers. Again, part of this interest on the side of the latter may be instrumental—to contain controversies, peddle a happy-ever-after vision of co-creation and, ultimately, push technology diffusion. But it would be hard to find an engineer today who does not recognize that the key questions concerning living labs and technology introduction more broadly are profoundly social. My own reading of interactions I have had in the domains of mobility and robotics indicate a genuine willingness to not repeat past mistakes and to embrace difficult conversations about what "getting things right" means.

A Cultural Turn in Innovation Studies?

In May 2018, the European General Data Protection Regulation (GDPR) came into effect after years of heated debate and anticipation. GDPR was greeted with much fanfare about a major economic bloc finally taking on the power and data racketeering of "Big Tech." At the same time, it prompted considerable panic about a suffocating bureaucracy for digital businesses and a potential death sentence for innovation in Europe vis-à-vis the US and China. At the heart of the debate was an uncomfortable double bind of, on the one hand, asserting a normative position, grounded in "European values," on the social transformations produced by innovation, while on the other hand fostering innovation in the name of global competition, growth, and social progress.

Questions about the relationship of innovation and culture have quietly moved to the center of current academic and policy debates on innovation. In what could be described as a "cultural turn" in innovation studies (Pfotenhauer et al. 2023), a growing number of authors have begun rethinking extant research in IS and economic geography through the lens of STS, with considerable resonance in the IS community. These authors are less interested in the mechanics or metrics of innovation, but in the "soft" cultural residues that mediate the relationship between innovation, social norms, and identity (Haddad and Benner 2021;

Pfotenhauer et al. 2019), the directionality of innovation policy (Schot and Steinmueller 2018), and diverse traditions of institutionalization (Irwin et al. 2021; Owen et al. 2021; Pfotenhauer and Jasanoff 2017).

These studies zoom in on the elusive role of "context," which has always prompted a lot of hand-waving in IS. While IS acknowledges that "one size does not fit all," much of the literature arguably still adheres to mechanistic and universalistic understanding of what innovation is, how it functions, who and what it requires, and how it can be replicated. Here, "culture" is often treated as something external to innovation itself and, if anything, the culprit for a model's underperformance when applied to new contexts (Delvenne and Thoreau 2012; Pfotenhauer and Jasanoff 2017). Constructivist studies like the ones cited above are being welcomed in innovation policy precisely because they offer different explanations for the frequent disappointments with innovation efforts.

At a more fundamental level, these works challenge another blind spot: the stubborn conceptual disconnect between innovation policy and technology governance as ostensibly different policy domains. Careful boundary work between these two domains has traditionally shielded the pro-innovation bias in public policy from the many controversies about particular innovations (plural, e.g., around emerging technologies). In today's era of heightened innovation controversy, however, this sleight of hand seems much less plausible. Policy-makers can no longer take the link between "more innovation" and the public good for granted. Few political mandates seem as pressing as how to better align innovation (both policy and technology) with questions of social cohesion, local identities, and unique political cultures. In this context, STS seems to provide welcome resources to investigate processes of meaning-making around innovation and thus for dealing with the second-order fallouts of innovation policy.

Conclusion

The three examples and the STS points they underwrite can be seen as evidence for an ongoing paradigm shift in innovation policy and scholarship. Many actors seem to aim for *better* innovation, not just *more* of it. That these points have been taken up in mainstream innovation policy settings, newspapers, and journals such as *Research Policy* suggests that normative concerns about the social impact of innovation are no longer a niche concern of STS, but are indeed front and center in many different communities. It further suggests that innovation scholarship and policy might be coming to terms with how they have been part of the problem, not just the solution (Irwin 2023). In a sense, it might not be just a shift towards "better innovation" but also towards "better innovation studies" we are witnessing—that is, an emergence of policy-oriented innovation scholarship that actively probes its own epistemic and political blind spots by seeking critical contributions.

Such successes, however modest, raise important normative questions about the identity of STS as a field—questions such as "What is critique and where does/can it speak from?" As a field concerned with power and reflexivity in the institutionalization of epistemic practices, STS has always been deeply ambivalent about its own "success" (Irwin 2006; Webster 2007). The history of the field knows many frustrating experiences of marginalization, power asymmetries, and instrumentalization when STS scholars have been invited to

engineering contexts on asymmetric terms ([Rabinow and Bennett 2012](#); [Shelley-Egan et al. 2018](#); [Viseu 2015](#)). Thus, much can be said, and has been said, about why the turn to responsibilization, co-creative experimentation, and cultural grounding are problematic or insufficient. After all, the examples discussed above clearly suggest that there is a long way to go.

Yet for me, arrival of STS sensitivities in mainstream innovation settings is also cause for pragmatic, albeit cautious, optimism—and tentatively good news for STS. STS knowledge seems to travel further and more easily into the centers of power of innovation than five to ten years ago, garnering more institutional backing and resources for messages that are still clearly off-mainstream. As a field that continues to struggle with institutional and disciplinary recognition, travailing in a world where innovation controversies make daily headlines, this visibility begets opportunity to find new allies for critical-reflexive engagement. At the very least, for those of us trying to bring STS insights to bear at institutions that unabashedly embrace innovation, it has arguably made our work easier, more productive, legible, and fun.

Acknowledgements

Author Biography

The author is a professor of innovation research and currently the chair of the STS Department at Technical University of Munich.

References

Beck, Ulrich. [1992](#). *Risk Society: Towards a New Modernity*. First Edition. Translated from German by Mark Ritter. London, England, Newbury Park, California, and New Delhi, India: SAGE Publications.

Birch, Kean, and D. T. Cochrane. [2022](#). "Big Tech: Four Emerging Forms of Digital Rentiership." *Science as Culture* 31(1): 44–58.
https://doi.org/10.1080/09505431.2021.1932794.

Delvenne, Pierre, and François Thoreau. [2012](#). "Beyond the 'Charmed Circle' of OECD: New Directions for Studies of National Innovation Systems." *Minerva* 50(2): 205–219.
https://doi.org/10.1007/s11024-012-9195-5.

Engels, Franziska, Alexander Wentland, and Sebastian M. Pfotenhauer. [2019](#). "Testing Future Societies? Developing a Framework for Test Beds and Living Labs as Instruments of Innovation Governance." *Research Policy* 48(9): 1–11.
https://doi.org/10.1016/j.respol.2019.103826.

Frahm, Nina M., Tess Doezema, and Sebastian M. Pfotenhauer. [2021](#). "Fixing Technology with Society: The Coproduction of Democratic Deficits and Responsible Innovation at the OECD and the European

Commission." *Science, Technology, & Human Values* 47(1): 174–216.
https://doi.org/10.1177/0162243921999100.

Frahm, Nina M. 2022. *Soft Constitutions: Co-Producing Neuro-Innovation and Society in the US, EU, and OECD.* PhD Dissertation. Technical University of Munich.

Gieryn, Thomas F. 2006. "City as Truth-Spot: Laboratories and Field-Sites in Urban Studies." *Social Studies of Science* 36(1): 5–38.
https://www.jstor.org/stable/25474429.

Haddad, Christian, and Maximilian Benner. 2021. "Situating Innovation Policy in Mediterranean Arab Countries: A Research Agenda for Context Sensitivity." *Research Policy* 50(7): 1–12.
https://doi.org/10.1016/j.respol.2021.104273.

Hilgartner, Stephen, Barbara Prainsack, and J Benjamin Hurlbut. 2017. "Ethics as governance in genomics and beyond." In *The Handbook of Science and Technology Studies*, edited by Ulrike Felt, Fouche Rayvon, Clark A. Miller, Laurel Smith-Doerr, 823–51. Fourth Edition. Cambridge, MA: MIT Press.

Hurlbut, J. Benjamin. 2017. *Experiments in Democracy: Human Embryo Research and the Politics of Bioethics*. New York: Columbia University Press.

Irwin, Alan. 2006. "The Politics of Talk: Coming to Terms with the 'New' Scientific Governance." *Social Studies of Science* 36(2): 299–320.
https://doi.org/10.1177/0306312706053350.

Irwin, Alan. 2023. "STS and Innovation: Borderlands, Regenerations and Critical Engagements*." Engaging Science, Technology, and Society* 9(2): 41–56.
https://doi.org/10.17351/ests2023.1363.

Irwin, Alan, Jane Bjørn Vedel, and Signe Vikkelsø. 2021. "Isomorphic Difference: Familiarity and Distinctiveness in National Research and Innovation Policies." *Research Policy* 50(4): 1–9.
https://doi.org/10.1016/j.respol.2021.104220.

Joly, Pierre-Benoit, Arie Rip, and Michel Callon. 2010. "Re-inventing Innovation." In *Governance of Innovation: Firms, Clusters and Institutions in a Changing Setting*, edited by Maarten J. Arentsen, Wouter van Rossum, and Albert E. Steenge, 19–32. Edward Elgar Publishing. Accessed March 4, 2016.
https://ideas.repec.org/h/elg/eechap/13020_2.html.

Knorr-Cetina, Karin. 1995. "Laboratory Studies: The Cultural Approach to the Study of Science." In *Handbook of Science and Technology Studies*, edited by Sheila Jasanoff, Gerald E. Markle, James C. Peterson, and Trevor Pinch. Second Edition. London, England: Sage.
https://doi.org/10.4135/9781412990127.

Kuhlmann, Stefan, Stegmaier Peter, and Kornelia Konrad. 2019. "The Tentative Governance of Emerging Science and Technology—A Conceptual Introduction." *Research Policy* 48(5): 1091–1097.
https://doi.org/10.1016/j.respol.2019.01.006.

Latour, Bruno. 1983. "Give Me a Laboratory and I Will Raise the World." In *Science Observed: Perspectives on the Social Study of Science*, edited by Karin Knorr-Cetina and Michael J. Mulkay, 141–170. London, England: Sage Publications.

Laurent, Brice. 2017. *Democratic Experiments: Problematizing Nanotechnology and Democracy in Europe and the United States*. Cambridge, MA: The MIT Press. https://doi.org/10.7551/mitpress/10580.001.0001.

Laurent, Brice, Liliana Doganova, Clément Gasull, and Fabian Muniesa. 2021. "The Test Bed Island: Tech Business Experimentalism and Exception in Singapore." *Science as Culture* 30(3): 367–390. https://doi.org/10.1080/09505431.2021.1888909.

Marres, Noortje. 2020. "Co-Existence or Displacement: Do Street Trials of Intelligent Vehicles Test Society?" *The British Journal of Sociology* 71(3): 537–555. https://doi.org/10.1111/1468-4446.12730.

Martin, Ben R., Paul Nightingale, and Alfredo Yegros-Yegros. 2012. "Science and Technology Studies: Exploring the Knowledge Base." *Research Policy* 41(7): 1182–1204. https://doi.org/10.1016/j.respol.2012.03.010.

Niewöhner, Jörg. 2016. "Co-Laborative Anthropology: Crafting Reflexivities Experimentally." In *Ethnological Interpretation and Analysis: Towards a Transparent Research Process*, edited by Jukka Joukhi and Tytti Steel, 81–25. Helsinki: Ethnos.

Organization for Economic Cooperation and Development (OECD). 2019. *OECD Recommendation on Responsible Innovation in Neurotechnology*. Adopted on December 11, 2019. Paris, France: Organisation for Economic Co-operation and Development. Accessed March 30, 2020. https://www.oecd.org/science/recommendation-on-responsible-innovation-in-neurotechnology.htm.

Owen, Richard, Mario Pansera, Phil Macnaghten, et al. 2021. "Organisational Institutionalisation of Responsible Innovation". *Research Policy* 50(1): 1–13. https://doi.org/10.1016/j.respol.2020.104132.

Pfotenhauer, Sebastian M., and Sheila Jasanoff. 2017. "Panacea or Diagnosis? Imaginaries of Innovation and The 'MIT Model' in Three Political Cultures." *Social Studies of Science* 47(6): 783–810. https://doi.org/10.1177/0306312717706110.

Pfotenhauer, Sebastian M., and Joakim Juhl. 2017. "Innovation and the Political State: Beyond the Myth of Technologies and Markets." In *Critical Studies of Innovation: Alternative Approaches to the Pro-Innovation Bias*, edited by Benoît Godin and Dominique Vinck, 68–94. Cheltenham, England: Edward Elgar. 68–94. https://doi.org/10.4337/9781785367229.00012.

Pfotenhauer, Sebastian M., Joakim Juhl, and Erik Aarden. 2019. "Challenging the 'Deficit Model' of Innovation: Framing Policy Issues under the Innovation Imperative." *Research Policy* 48(4): 895–904. https://doi.org/10.1016/j.respol.2018.10.015.

Pfotenhauer, Sebastian M., Nina Frahm, David Winickoff, et al. 2021. "Mobilizing the Private Sector for Responsible Innovation in Neurotechnology." *Nature Biotechnology* 39(6): 661–664. https://doi.org/10.1038/s41587-021-00947-y.

Pfotenhauer, Sebastian M., Brice Laurent, Kyriaki Papageorgiou, and Jack Stilgoe. 2021. "The Politics of Scaling." *Social Studies of Science* 52(1): 3–34.
https://doi.org/10.1177/03063127211048945.

Pfotenhauer, Sebastian M., Alexander Wentland, and Luise Ruge. 2023. "Understanding Regional Innovation Cultures: Narratives, Directionality, and Conservative Innovation in Bavaria." *Research Policy* 52(3): 1–18.
https://doi.org/10.1016/j.respol.2022.104704.

Pinch, Trevor. 1993. "'Testing – One, Two, Three . . . Testing!': Toward a Sociology of Testing." *Science, Technology, & Human Values* 18(1): 25–41.
https://www.jstor.org/stable/689699.

Rabinow, Paul, and Gaymon Bennett. 2012. *Designing Human Practices: An Experiment with Synthetic Biology*. Chicago: University of Chicago Press.

Schot, Johan, and W. Edward Steinmueller. 2018. "Three Frames for Innovation Policy: R&D, Systems of Innovation and Transformative Change." *Research Policy* 47(9): 1554–1567.
https://doi.org/10.1016/j.respol.2018.08.011.

Shapin, Steven, and Simon Schaffer. 1985. *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*. Princeton, NJ: Princeton University Press.

Shelley-Egan, Clare, Diana M. Bowman, and Douglas K. R. Robinson. 2018. "Devices of Responsibility: Over a Decade of Responsible Research and Innovation Initiatives for Nanotechnologies." *Science and Engineering Ethics* 24(6): 1719–1746.
https://doi.org/10.1007/s11948-017-9978-z.

Stilgoe, Jack, Richard Owen, and Phil Macnaghten. 2013. "Developing a Framework for Responsible Innovation." *Research Policy* 42(9): 1568–1580.
https://doi.org/10.1016/j.respol.2013.05.008.

Stirling, Andrew. 2008. "'Opening Up' and 'Closing Down': Power, Participation, and Pluralism in the Social Appraisal of Technology." *Science, Technology & Human Values* 33(2): 262–294.
https://doi.org/10.1177/0162243907311265.

Tennant, Chris, and Jack Stilgoe. 2021. "The Attachments of 'Autonomous' Vehicles." *Social Studies of Science* 51(6): 846–870.
https://doi.org/10.1177/03063127211038752.

Viseu, Ana. 2015. "Caring for Nanotechnology? Being an Integrated Social Scientist." *Social Studies of Science* 45(5): 642–664.
https://doi.org/10.1177/0306312715598666.

Webster, Andrew. 2007. "Crossing Boundaries Social Science in the Policy Room." *Science, Technology, & Human Values* 32(4): 458–478.
https://doi.org/10.1177/0162243907301004.

Winickoff, David E., and Sebastian M. Pfotenhauer. 2018. "Technology Governance and the Innovation Process." In *OECD Science, Technology and Innovation Outlook 2018: Adapting to Technological and Societal Disruption*, 221–240. Paris, France: OECD Publishing.
https://doi.org/10.1787/sti_in_outlook-2018-en.