Social Science Contributions Compared in Synthetic Biology and Nanotechnology

Philip Shapira,[a,b,c,*] Jan Youtie,[c,d] and Yin Li[c]

[a]Manchester Institute of Innovation Research, Manchester Business School, University of Manchester; [b]Centre for Synthetic Biology of Fine and Speciality Chemicals, Manchester Institute of Biotechnology, University of Manchester; [c]School of Public Policy, Georgia Institute of Technology; [d]Georgia Tech Enterprise Innovation Institute. *Email: pshapira@mbs.ac.uk

Researchers in the social sciences (including humanities, law, ethics, and business) are increasingly involved in analyzing and reflecting upon societal aspects of emerging technologies. The late 1980s and 1990s saw growth in ethical, legal, and social implication (ELSI) work via the Human Genome Project. In the 2000s, research on the societal implications of nanotechnology developed in the US, Europe, and other countries. For example, beginning in the mid-2000s, the US National Nanotechnology Initiative (NNI) supported a range of nanotechnology in society research activities including two national centers. (2.7% of the NNI budget was assigned to societal and educational concerns by 2009, although subsequently declining.) Most recently, attention has been given to issues of responsible research and innovation in a range of emerging technologies. As consideration focuses on societal concerns and social science research agendas in synthetic biology (synbio), we probe what might be learned by comparison with social science research outputs from earlier rounds of emerging technologies, particularly nanotechnology. Societal research in nanotechnology and synbio both occur in what might be called a post-GMO (genetically-modified organism) setting in which science comes under greater public scrutiny, and expectations are heightened related to accountability, deliberation, and responsibility and to the societal relevance of research and innovation. At the same time, any comparisons need to take account of contextual differences: whereas there was relatively little dedicated research capability in place prior to the ramp-up of societal research in nanotechnology, societal research in synbio today draws upon a well-established infrastructure of ELSI life science research in biotechnology, human genome, and health domains with many ELSI investigators co-located in transdisciplinary centers comprised of medical researchers, bioethicists, and legal investigators.

We can see that societal research outputs in synthetic biology are already burgeoning. A Google Scholar analysis (by the authors) for the period 2004 to 10/10/2014) finds more than 500 publications (including journal articles, policy reports, books, and working papers) that consider societal aspects of synbio; of these, about three-fifths were published since 2010 ("societal aspects" here includes publications oriented towards social science, humanities, philosophical, business, legal, intellectual property, regulatory, governance or policy). Google Scholar offers broad indications of output scale and picks up a wide range of publications; however, to more finely analyze the characteristics of research outputs, we need to use analytical approaches applied to other structured publication databases. We are particularly interested to explore the underlying knowledge sources and clusters underlying societal research in synbio bio and do so by making a comparison with an earlier study we undertook in the nanotechnology social science subdomain. We compare these two subdomains at similar developmental points, in the initial period of social science investment – through to 2007 for nanotechnology social science research and through to May 2014 for synbio social science research. These two periods encompass roughly the same number of social science articles (approximately 300) extracted from the Web of Science Social Science and Arts and Humanities Index and the Scopus Social Science and Humanities category. Our focus is on the knowledge clusters used in these social science studies (for this analysis, the multidisciplinary journals Science, Nature, and Proceedings of the National Academy of Sciences are excluded as they also include natural science papers). We use a methodology based on analysis of cited references (also known as "backward citations"). One common interpretation of cited references is that they reflect knowledge bases and flows used in a research article. The method used focuses on highly cited authors (cited by a threshold number of articles); using a Person name fuzzy list cleanup algorithm to obtain this list, applying multi-dimensional scaling to co-citations of authors; and taking the results down to two-dimensional space to produce a network map of the results in which the nodes represented the number of papers citing the work and the links represent the degree of association between the nodes (after applying a path-erasing algorithm to focus on the strongest links).

Our earlier study [1] of cited references found eight social science areas represented in the nanotechnology social science subdomain (Figure 1). These were: science visions (including science fiction), scientometrics, public perception and deliberation, governance, ethics, science and technology, and a hub represented by citations to M. Roco of the National Science Foundation and a highly recognized public entrepreneur. The relative use of citations in these areas changed over time, with science visions articles being cited more in the early years, then other central social science areas being cited more in the later years. Applying the same method to synbio [2], we find a different set of disciplines represented in the peer-reviewed societal research literature to date (Figure 2). Synbio social science knowledge citations focus on a large cluster of bioscientists and bioengineers; an overlapping cluster of history and philosophy researchers; an overlapping cluster comprised of science and technology studies, law, governance, ethics; and a cluster citing the private entrepreneurial scientist Craig Venter. These results surely reflect the differences in pre-contexts between nanotechnology and synbio. The prior ELSI research legacy is providing an important pathway for current synbio societal research, but comparison suggests that gaps are also present. Relatively less influential in synbio social science are papers by scientists with visionary perspectives. Also, several social science knowledge bases evident in the nanotechnology map are not yet widely present in synbio research, particularly public perception and deliberation, scientometrics (including quantitative analyses of research and innovation trajectories), and economics. We should discuss whether and how synbio social science research can incorporate greater outward-looking, engagement, anticipatory, and downstream perspectives.

Figure 1. Nanotechnology Social Science Citation Clusters

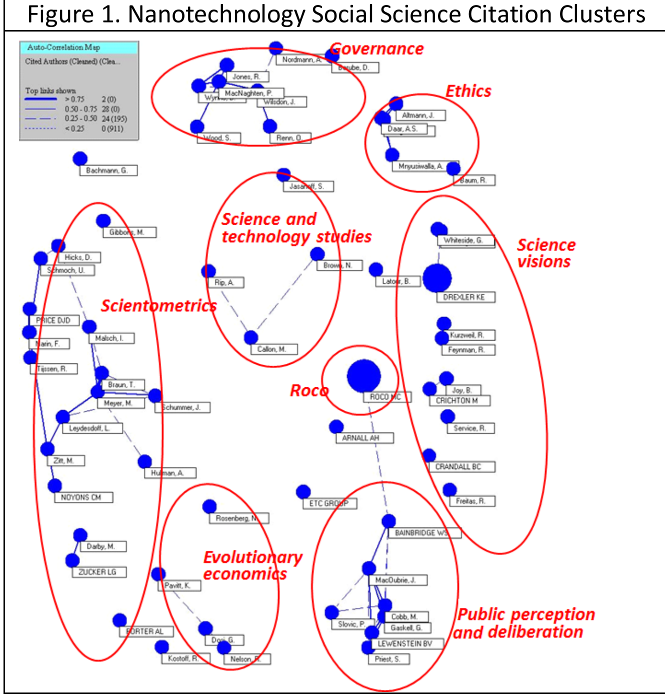
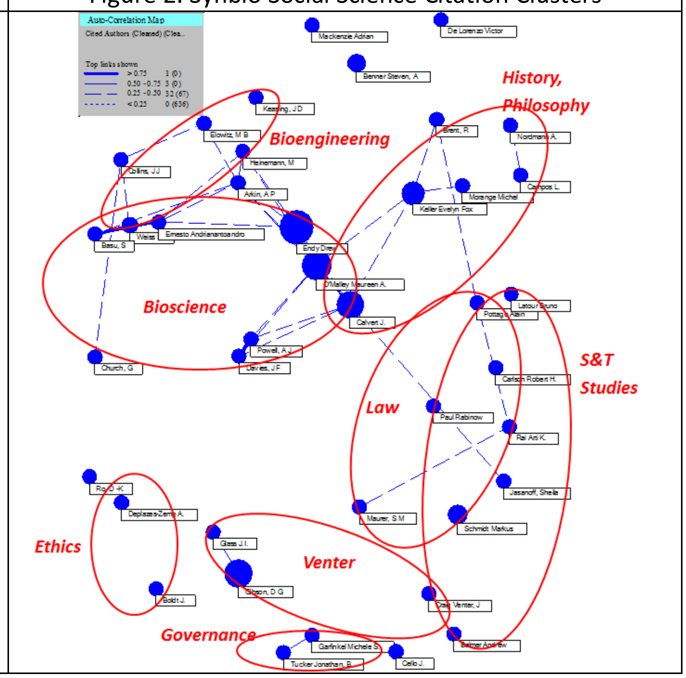


Figure 2. Synbio Social Science Citation Clusters



Source: Analysis of Web of Science & Scopus, 308 nanotechnology social science articles (7.2K backward citations) through 2007 and 314 synbio social science articles (8.7K backward citations) through May 2014. For discussion of methods and results, see [1] and [2]. **References**: [1] Shapira, P., Youtie, J., Porter, A.L. (2010). The Emergence of Social Science Research in Nanotechnology. *Scientometrics* 85(2), 595-611. [2]Youtie, J., Shapira, P. (2014). A Comparison of Social Science Research in Synthetic Biology and Nanotechnology, Working Paper.