
Special Section: Negotiations and Conflict Resolution During the Global Pandemic

Negotiated Sharing of Pandemic Data, Models, and Resources

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*Urgent responses to the COVID-19 pandemic depend on increased
collaboration and sharing of data, models, and resources among*

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scientists and researchers. In many scientific fields and disciplines, institutional norms treat data, models, and resources as proprietary, emphasizing competition among scientists and researchers locally and internationally. Concurrently, long-standing norms of open data and collaboration exist in some scientific fields and have accelerated within the last two decades. In both cases—where the institutional arrangements are ready to accelerate for the needed collaboration in a pandemic and where they run counter to what is needed—the rules of the game are “on the table” for institutional-level renegotiation. These challenges to the negotiated order in science are important, difficult to study, and highly consequential. The COVID-19 pandemic offers something of a natural experiment to study these dynamics. Preliminary findings highlight: the chilling effect of politics where open sharing could be expected to accelerate; the surprisingly conservative nature of contests and prizes; open questions around whether collaboration will persist following an inflection point in the pandemic; and the strong potential for launching and sustaining pre-competitive initiatives.

Keywords: COVID-19, pandemic, negotiations, data, models, resources, stakeholders, interests, alignment, institutions, rules of the game, forums, negotiated order

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Introduction

In response to the COVID-19 pandemic, social institutions are challenged—with some rising to meet the challenge and others falling short. Societal challenges often require rapid and significant change. Some fields, disciplines, and domains are accelerating preexisting patterns of collaboration and open sharing of data, models, and resources in response to the crisis. Others face a need to rapidly shift deeply embedded norms, practices, and assumptions that are highly competitive and individualistic; such changes are difficult to bring about (Seo and Creed 2002; Conrad and Thelen 2016). These institutional challenges provide insights into negotiations that happen when the rules of the game—the negotiated order in society (Strauss 1978) and in science (Mosconi et al. 2019)—are themselves “on the table” for negotiation. The global pandemic raises core questions regarding the legitimacy of aspects of the existing order, resulting in the simultaneous renegotiation of both micro interactions and the macro context (Bitektine and Haack 2015).

The urgency and seriousness of the COVID-19 pandemic underscore our collective unwillingness to tolerate delay, waste, or unnecessary redundancy in finding solutions and tools to respond to pressing health and policy needs. Collaboration and open sharing of COVID-19 data, models, and resources offer the promise of efficiency and innovation. Science is collaborative in many ways, as evidenced by the rise of common databases such as the GenBank (Bensen et al. 2013) for genomic data (which rapidly hosted the SARS-CoV-2 genome sequence in March 2020), the growth in multiauthored articles, and the increased use of open-source resources. Still, deeply embedded assumptions in many fields, disciplines, and domains consider data, models, and resources as proprietary (Bolukbasi et al. 2013). Core practices and traditions in the academy and in industry center on individual credit for accomplishments, competitive dynamics for talent and, in the commercial sector, economic

dominance. The calls for collaboration and sharing in response to the pandemic have presented macro level challenges to these proprietary and competitive norms (Ienca and Vayena 2020; Moorthy et al. 2020).

This article begins with the core question of whether collaboration initiated in a time of crisis will persist afterward. We review foundational principles from institutional and negotiation theory, along with the methods associated with our related ongoing research. Three aspects of negotiated change in the context of the pandemic (the stakeholders and interests, the rules of the game, and forums, both present and absent) are then addressed, with illustrative examples. Finally, we note methodological limitations to this initial research report and offer preliminary conclusions on the challenges and opportunities associated with the open sharing of data, models, and resources during the global pandemic.

A Transformational Historical Moment or a Snap-Back?

At the core of our overall research project is the institutional question: Will this historical moment prove transformational for key aspects of the science enterprise, thereby ushering in a new, more collaborative negotiated order? Or will it just be a temporary period of increased collaboration and sharing, then snap back to pre-pandemic ways? History and even philosophy provide insights into this question.

Toward the end of World War II, global leaders came together to negotiate a new world order in response to what was viewed as a crisis of massive scale, threatening civilization with a range of destructive technologies never before seen. The 1942 Declaration of the United Nations (Meisler 2011) and the 1944 Breton Woods Agreement on international monetary policy (James 1996) set the stage to operationalize important institutions as part of the post-war international negotiated order. The COVID-19 pandemic may present a similar historical moment, in which we face a set of global public health and economic existential threats and in which a new era of collaboration in science and research may be on the horizon. Like the World War II precedents, this argument would hold that now, during the crisis, is the time to negotiate the pre-agreements to set the stage for collaboration and sharing as a new negotiated order when the crisis is over.

However, a new negotiated order does not necessarily follow a crisis—often things simply go back to the way they were before, either by design or by a more organic reversion. Thomas Aquinas acknowledged in the *Summa Theologica* that, during a famine, food must be held in common, but that a return to private property and a market-based system is appropriate after a crisis (Aquinas 1911 translation). This argument was rooted in Aristotle's writing in the *Nicomachean Ethics* in which famine—an existential crisis—was seen as a temporary disruption of proprietary arrangements, with a return to the previous norm following the

crisis (Aristotle 2011 translation). This suggests that a new era of open science following the pandemic and economic crisis may be unrealistic, politically infeasible, and perhaps ethically inappropriate. Indeed, with the closing or reduced operation of scientific labs not involved in COVID-19 research, there may be a long period of recovery needed even to get back to pre-pandemic levels of operation, let alone to expect anything new.

The Depth of the Challenge

SARS-CoV-2 (the virus behind the COVID-19 illness) is highly communicable, with the risk of severe short- and long-term impacts on health, including death. The scale of the pandemic overloads health care systems, with some regional limits in available intensive care hospital beds and medical supplies contributing to the death toll (Moghadas et al. 2020). Long-term risks for survivors include impaired breathing, coagulopathy, and brain impairment (NIH 2020a). The magnitude of the threat is clear as experts in virology and vaccinology put aside ongoing work with an immediate commitment to make sense of the novel pathogen, to identify potential targets for treatments and vaccines, and to begin to design and initiate clinical trials. The size of the problem and opportunity is evident as regulators and principals in the pharmaceutical and biotechnology industries have shared key information and called for collaboration in the development of a nonproprietary hyperimmune serum for treatment, combined with an array of changes leading to rapid cycling of regulatory approval for emergency use applications, investigations of new drugs, and clinical trial applications for vaccines and treatments (Liu et al. 2020). Importantly, among the key information shared is a review of existing patents relevant to the pandemic, which provide valuable public information while also revealing proprietary boundaries. What remains to be seen is the extent to which these new arrangements will persist after the pandemic and the extent to which such work now is fully open and broadly shared.

Accompanying the public health threat are the early and extensive shutdowns of businesses, schools, transit, and social interaction, precipitating what is proving to be the worst economic collapse since World War II (World Bank 2020). Further challenging the institutions of science is the growing evidence of racial and economic disparities in the impact of COVID-19, prompting concurrent attention to embedded assumptions, practices, and norms that are reflective of institutional racism, gender bias, and other forms of discrimination. These are spurring reexamination of core assumptions in the institutions of science (AEA 2020) that add a socioeconomic and political complexity to the work on pandemic data and models. Scientific knowledge is never independent of the societal context (Latour 1993), but the current challenges throw

these interdependencies into sharp relief. This is evidenced in the politicization of pandemic models.

Economic assumptions that reinforce proprietary views of data are a deeply embedded element of the current sharing challenges, but are not typically acknowledged in the calls for open sharing of data, models, and resources. There have been recent calls for rethinking the broader social implications of neoliberal markets (Piketty 2014; Kashwan, MacLean, and García-López 2019) that are beyond the scope of this article. However, there are elements of the broader economic context that are relevant. For commercial firms, the Trade-Related Aspects of Intellectual Property Rights (TRIPS), which went into effect in 1995, institutionalized competitive norms that shape interactions involving biomedical firms and other economic actors during the pandemic (TRIPS 1995; Odell 2000). For university researchers, the Bayh-Dole Act (35 U.S.C. ch. 30 § 301), which went into effect in 1980, gives universities rights to the intellectual property associated with innovations arising from federally funded research. Designed to foster innovation and economic development, Bayh-Dole institutionalized competitive norms among universities, many of whom now have offices dedicated to commercializing innovations created by their researchers. This brings a focus on intellectual property and the proprietary interests of universities in their research data and models as university researchers respond to the pandemic.

Exceptions to the dominant competitive and proprietary regimes in the commercial and university sectors do exist, including public-private partnerships that carve out pre-competitive spaces, such as the BioMarkers Consortium (Mittleman, Neil, and Cutcher-Gershenfeld 2013). These alternative institutional arrangements simultaneously maintain the logic of competition while identifying clearly defined spaces for collaboration. They serve as examples that could be adapted to engage the current crisis.

The larger context provides both a sense of urgency and reason for caution associated with the renegotiation of institutional norms, involving a complex combination of issues around public health, economics, and social justice. There are both drivers of much needed institutional change and countervailing forces that can undercut a shift toward increased sharing, collaboration, and inclusion. Foundational principles from institutional and negotiation theory offer potential paths forward, though success is far from assured.

Institutional Theory

In 1911, sociologist Robert Michels documented how political parties, trade unions, and other institutional arrangements were formed with a particular mission, but these institutional entities quickly focused on

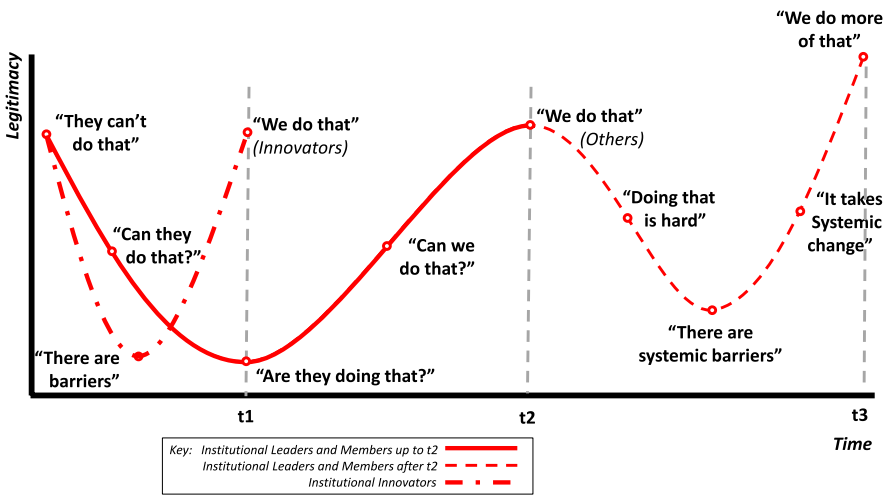
ensuring their continued existence, irrespective of the stated mission (Michels 1911 translation). He called this dynamic “the iron law of oligarchy,” with the institutional leaders in the role of oligarchs. Institutions, in effect, are hardwired to be conservative and resistant to changes that could undermine their existing operations. In 1962, Thomas Kuhn documented how “normal science” also behaves in ways similar to what Michels predicted. The result, Kuhn observed, were periodic revolutions in theory and methods since new developments that did not fit the established paradigm were resisted until the evidence was overwhelming—literally overwhelming the established paradigm in what he described as a series of scientific revolutions. While subsequent critiques of Kuhn’s work challenge the specifics of certain historical developments and other aspects of his analysis, his work continues to be valued for seeing science not as an immutable institution, but as a socially constructed set of arrangements (a negotiated order) where thought leaders can and frequently do serve as gatekeepers (Scharff and Dusek 2020).

If we unpack further the foundational dynamics highlighted by Michels and Kuhn, we see that institutions are the product of patterned behaviors (North 1991). The patterns are repeated until they become deeply embedded, often unstated, assumptions that define an organizational culture and, for this analysis, an institutional culture (Schein 1985). Thus, changing institutions requires changing these deeply embedded assumptions and constantly repeated patterns of behavior. Reinforcing these patterns are institutional leaders who exercise power directly and in less visible ways by controlling what is and is not on the agenda, particularly with common-pool resources (Brisbois, Morris, and Loë 2019). Shifts in the patterns are rarely continuous, but rather a series of pivotal events where the institutional arrangements are “on the table”—sometimes pivoting toward a new negotiated order and sometimes failing to pivot, reinforcing the existing order (Cutcher-Gershenfeld 2020).

Governing institutional interactions are norms and assumptions about what has been referred to as the “they” in organizations (Lawrence 2011). “They” is an embodiment that influences what is and is not seen as legitimately on the agenda, with legitimacy being something that can be managed, but not easily (Suchman 1995). In everyday language, the role of “they” in institutional change can be seen as a progression from: “They can’t do that.” to “Can they do that?” to “Are they doing that?” to “Can we do that?” to “We do that.” This progression is illustrated in the solid line in Figure One, which traces legitimacy over time for institutional leaders/members relative to institutional innovators.

The innovators with the dot/dash line are doing something new at t1, which is the same time that institutional leaders and members are only becoming aware of something new. The institutional leaders

Figure One
Institutional Leaders and Members, and Innovators Over Time
 [Colour figure can be viewed at wileyonlinelibrary.com]



and members have to renegotiate norms and assumptions to get to t2 where they too are doing something new. At that point, the institutional leaders and members face additional challenges to legitimacy as they discover that even successful pilot experiments are hard to diffuse and institutionalize. This is, of course, just a symbolic representation with the actual amplitude and dynamics different in each case. The cycles show advances in legitimacy even at the new low point between t2 and t3, but other dynamics are possible, including the potential for a crisis of legitimacy such that the innovation does not advance at all.

For nearly a decade before the arrival of COVID-19 there have been increasing calls for more collaboration in science and for scientific data to be more open, as we document in more detail below. In response, fields and disciplines have ranged from those that are still in the “They can’t do that.” stage (particularly fields where methods are individualistic and data is hard to standardize) to those that say sharing and collaboration are what we do (particularly where methods are highly standardized and there is a requirement for sharing scarce experimental or compute resources). So the renegotiation of norms in science during and beyond the COVID-19 pandemic is not a unitary institutional change challenge, but a case of engaging a diverse and complex mix of norms, practices, and assumptions across an array of fields, disciplines, and domains to meet an urgent societal need.

Negotiation Theory

Central to negotiation and conflict resolution theory are the principles and methods for identifying and changing underlying assumptions at the individual and collective level. In 1932, as the inaugural speaker at the founding of the School of Business Administration at the London School of Economics, economist Mary Parker Follett challenged the pervasive assumption that negotiations required either (1) winners and losers or (2) both parties compromising such that neither achieved its aims. Instead, she introduced the idea of a “third option,” which she termed “integration” (Follett 1940). This involved more fully understanding each party’s aspirations and combining (integrating) them in ways that would expand the proverbial pie to generate agreements that neither had in mind at the outset and that made both better off. In 1965, Richard Walton and Robert McKersie paired Follett’s concept of integrative bargaining with distributive bargaining as an inevitable feature of interactions that involve parties with common and competing interests. Both creating and claiming are results in negotiations (Lax and Sebenius 1987) and both are involved in renegotiating a negotiated order. In the conflict resolution arena there is now a vast literature on transformative mediation that centers on reframing what are seen as conflicting positional statements that are highly distributive into alternative, more integrative sets of interests (Fisher, Ury, and Patton 1991; Bush and Pope 2002), also relevant when the negotiated order is “on the table.”

Walton and McKersie also documented attitudinal dynamics that can complicate or advance constructive interactions, as well as the internal negotiations within any party in order for it to reach agreement with the other party. Current commentaries on negotiation in the context of the pandemic focus on these attitudinal dynamics at the individual level of analysis (Najam 2020). Here we concurrently trace dynamics at the institutional level.

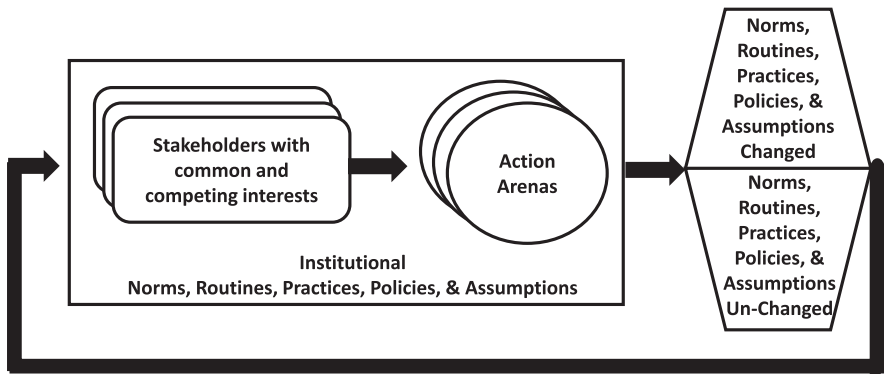
Institutional-level negotiations around new patterns of collaboration and COVID-19 data sharing take place in what Nobel Prize-winning institutional economist Elinor Ostrom termed “action arenas” (2005). Examples of action arenas are multi-stakeholder consortia, public–private partnerships, task forces and subcommittees of professional societies, public comment requests by agencies, legislative forums, social movement hashtags, open source digital platforms, communities of practice, and more. In general, people focus on terms and conditions as the output of negotiations, but negotiations in these action arenas can also serve to codify emerging innovation and set the stage for further innovation. Ostrom found that public–private partnerships and other innovative institutional arrangements were superior to either markets or regulation when

it came to common-pool resources such as water in farming communities. Ostrom’s collaborative approach does have limits, such as when there are large power imbalances, as was observed in an earlier cited study on the governance of common-pool resources (Brisbois, Morris, and Loë 2019). However, these forums for negotiation can enable new routines or practices to emerge that then serve as institutional “shock absorbers” (Berente et al. 2016), easing the journey to a new negotiated order.

For collaborative institutional arrangements to succeed, diverse stakeholders need to align shared interests, but there will inevitably remain some points of disagreement and conflicting interests. Thus diverse stakeholders in complex systems often settle on a form of negotiated order (Strauss 1978), whereby they encourage and enforce cooperation while maintaining independence and discretion. A negotiated order requires certain “rules of the game” (Raiffa 1982; Cutcher-Gershenfeld 1994) that are negotiated early in the collaboration and evolve over time.

Figure Two represents a process of renegotiating the negotiated order. Note that there are many stakeholders, each with common and competing interests, and there are multiple possible action arenas. The interactions all take place in the context of the existing norms, practices, policies, and assumptions. The result can be a change in norms, practices, policies, and assumptions, but change is not assured (such as in the case of large power imbalances). It is not necessary for all stakeholders to be fully aligned on all relevant interests for the action arena to produce change, but there needs to be sufficient alignment within each stakeholder and across the stakeholders for aspects of a new negotiated order to be established. Of course, whether or not there

Figure Two
Renegotiating the Negotiated Order



is change, the cycle continues, with new norms, practices, policies, and assumptions as the new context for dialogue and action.

In most calls for science to be more open and collaborative, there is an implicit assumption that it is an action arena with a negotiated order that will enlarge the proverbial pie for all. But there are distributive and attitudinal dynamics centered on short-term self-interest that can surface in these action arenas. Indeed, game theory clearly points to the ways that individual self-interests consistently undercut collective interests—a dynamic that Mancur Olson documented as part of the “logic of collective action” in 1965 and that Garrett Hardin, in 1968, popularized as the “tragedy of the commons.” Inaction, conflict, and collective loss at the institutional level become the product of aggregated, self-interested individual behaviors, something that current game theorists are highlighting in the context of the pandemic (Dhawan and Chakrabarti 2020).

One way of overcoming the tragedy of the commons is for one or more individuals to show leadership and act in the collective interest—in effect introducing new patterns of interaction. Science is a massive enterprise, spanning universities, industry, government labs, state and federal agencies, private foundations, publishers, professional societies, and citizen scientists. Thus, attempting to identify the full scope of changes in the norms, practices, and culture across the science enterprise is beyond the scope of this article. Instead, we are tracking illustrative cases that may be harbingers of lasting change in the negotiated order or just a temporary response that will snap back as the iron law of oligarchy reasserts itself. In effect, this article begins the conversation, but does not conclude it.

Methods

This preliminary research report combines action research, interview-based research, and archival analysis. The action research approach involves self-documentation by participant-observers who are directly engaged in social problems (Lewin 1946), organizational change (Argyris 1970; Schein 1999), information systems (Avison, Lau, Myers, and Nielsen 1999), and other domains (Greenwood and Levin 2007). In our case, members of the Stakeholder Alignment Collaborative have been directly involved in the sharing of COVID-related data, models, and resources, as well as broader initiatives centered on the open sharing of data in science. This introduces potential bias in the analysis, as well as unique insights that derive from direct engagement. We have also begun conducting semi-structured interviews with key stakeholders, some of whom are quoted by name in the article. This provides additional perspectives beyond our own direct experience. The interview protocol was approved by the Brandeis Institutional Review Board.

Further, we draw from online threaded dialogue, archival information in public records, and selected results from prior survey research we have conducted on the open sharing of data, models, and software in science. Our COVID-19 research is continuing, with additional interviews and a broader stakeholder survey anticipated, so this article is a preliminary report on early findings, subject to adjustment as further evidence is collected.

The semi-structured interviews are with a cross-section of modelers of pandemic data, leaders in digital fabrication, and facilitators of cyberinfrastructure computing resources. Concurrently, we have been interviewing leaders in foundations, multi-stakeholder consortia, and professional societies to understand how the institutional contexts serve to enable collaboration and sharing. To date we have conducted seven semi-structured interviews with university researchers, four with industry researchers/practitioners, and five with additional key institutional stakeholders.

The coauthors of this article include fourteen university researchers, three industry researchers/practitioners, and two institutional stakeholders, all of whom are directly involved in research and engagement with the open sharing of scientific data, models, and resources. We are a multi-stakeholder collaborative, operating for over five years on a virtual basis—so we are operating as a collaborative even as we are studying collaboration. Members of our group are active in data sharing collaborations, such as the World Data System (WDS), Research Data Alliance (RDA), International Science Council's Committee on Data (CODATA), Council of Data Facilities (CDF), FAIR Data Initiative, Campus Research Computing Consortium (CaRCC), Minority Serving- Cyberinfrastructure Consortium (MS-CC), and others.

In considering what will happen following the pandemic, it is important to clarify what is meant by the concepts of “during” and “following” the pandemic. In mathematical terms, we can define the separation of these two periods by the shift in the inflection point on a global basis—the point at which the pandemic is no longer expanding. It is possible, of course, that the period afterward will still be marked by periodic waves of infection, absent an effective vaccine and/or medical therapies, such that the “following” period could still be one with grave health threats. For the purposes of our core research question on changes during and following the pandemic, we will assume that it is possible to conceive of periods during and following the pandemic, even if the reality proves more complicated.

Stakeholders and Interests

We begin with the assumption that collaboration and sharing of data, models, and resources relevant to the COVID-19 pandemic involves diverse stakeholders, each of whom has interests that may be supporting and constraining. As we have noted, preceding the pandemic there have been increased calls for collaboration in science, which have been accelerating in the past decade. For example, in 2013 the U.S. Office of Science and Technology Policy issued a letter to the heads of federal agencies calling for increased access to data and scholarly articles resulting from federally funded scientific research (OSTP 2013). There were similar policy announcements at the same time from the European Union (EU 2013), Australia (Office of Australian Information Commissioner 2013), and other locations. Beyond the merits of ensuring reproducibility in science, the U.S. OSTP letter stated that open sharing policies “will accelerate scientific breakthroughs and innovation, promote entrepreneurship, and enhance economic growth and job creation.” So the motivation to share, preceding the COVID-19 pandemic, was as much about economics and other societal interests as it was about science.

In response to the OSTP and other policy announcements, many associations, publications, funders, and consortia increased their statements and efforts in support of the sharing of research data, models, and resources. While this translated into notable changes in practice, such as all leading geoscience journals requiring the submission of reusable datasets (not just flat PDF files as “supplements”), there are still large numbers of scholars engaged in federally funded research who view their data as proprietary. As one respondent commented, at the extreme, on a 2015 stakeholder survey of 449 scientists that we conducted on data sharing in the geosciences, “I am going to my grave with my disk drive in my cold dead hands” (Stakeholder Alignment Collaborative 2017). This statement was made a half-dozen years after the relevant funding agency required data management plans for all funded research. In the same survey, when asked about finding, accessing, and integrating multiple datasets, models, and/or software, the importance of such activities was rated 8.4 (0 = not important; 10 = very important); its easiness was rated 4.5 (0 = very difficult; 10 = very easy). When asked if their employer/organization will value and reward their efforts to support open sharing and reuse, the average response was a moderate 5.5 (0 = strongly disagree; 10 = strongly agree). Only a subset of 57 percent said they had submitted a data management plan as part of a research proposal and 90 percent of the subset (or 51 percent total) of that group said the plan included making data publicly available.

Further, only 76 percent of that group (or 39 percent total) reported having done so (Cutcher-Gershenfeld et al. 2018). There is evidence that the numbers are worse in economics and management, with one study finding that 81 percent of researchers do not voluntarily share their data (Andreoli-Versbach and Mueller-Langer 2014). Thus, the calls for collaboration and sharing during the pandemic arise in a context in which the recent past features a combination of momentum and inaction or resistance, evidence of the presence of the iron law of oligarchy and the strength of the proprietary negotiated order.

Although we can't outline here all of the stakeholders relevant to sharing COVID-19 data, models, and resources and their interests, Table One provides a partial listing that signals the complexity of the challenge. Of course, at an individual or research team level, negotiation is required in all aspects of data sharing and reuse, ranging from its acquisition, its interpretation, its curation, its oversight, and its applications. The associated interests are organized in three categories for those that are generally shared, those that are primarily competitive, and those that have aspects that are both common and competitive. Note that the three combined stakeholder categories are not monolithic—there are some people in each category who will have stronger or less strong views on all of the listed interests. Completing a chart like this is an important step in preparing for a negotiation, so we provide it as a possible discussion starter for stakeholders in action arenas.

Each of the interests listed in Table One has institutional arrangements within the existing negotiated order that are reinforcing or complicating. For example, the interests of scholars to get credit for individual accomplishments or the interests of commercial firms to be winners of the COVID-19 innovation race are reinforced by institutional arrangements associated with university tenure and promotion for academics and stock market valuation for businesses. The iron law of oligarchy predicts that universities and the commercial sector will be resistant to change. At the same time, concern with revealed disparities, which is a widely shared interest, may not figure prominently in the incentive structures facing most of the stakeholders. That may change given the degree to which these issues are resonating in society, but it was not the case prior to this historical moment. Pre-competitive partnerships are of particular interest because they advance interests around collaboration, while still allowing for competitive interests to operate.

Rules of the Game

Negotiators know that one of the most important parts of any negotiation centers on establishing the “rules of the game,” which itself is a negotiation—a process of bargaining over how to bargain (Raiffa 1982;

Table One
Stakeholders and Interests Relevant to the Sharing of COVID-19 Data, Models, and Resources

Types of Stakeholders	
Types of Interests	Institutional Actors (Foundations, Publishers, Funding Agencies, Associations, Consortia)
<p>Common Interests</p> <ul style="list-style-type: none"> • Accelerating advances in response to the pandemic • Concern with revealed disparities in society • The exhilarating joy of scientific discovery • Discovering new colleagues with complementary research interests • Increasing the sharing of data, models, and resources following the pandemic • Helping people, saving lives • Rigor, quality, reproducibility 	<p>University Scientists and Researchers</p>
<p>Competing Interests</p> <ul style="list-style-type: none"> • Career advancement and recognition • Market advantages • Shareholder returns • Protecting intellectual property associated with new innovations • Cultural norms seeing data, models, and resources as proprietary 	<p>Increased institutional legitimacy (ahead of others) for advances that have been supported</p> <ul style="list-style-type: none"> • Career advancement and recognition (ahead of others) for advances in knowledge • Not being “scooped” by others re-using data, models, and resources • Increased prospects for current and future funding of research • Cultural norms seeing data, models, and resources as proprietary
<p>Additional Interests (mixed)</p> <ul style="list-style-type: none"> • Ensuring sufficient cyberinfrastructure, communications, and other mechanisms to support the sharing of data, models, and resources 	<p>Administrative costs not part of budget and planning</p> <ul style="list-style-type: none"> • Competition for a limited set of resources (financial, material, and human capital) • Regulatory and/or legal compliance

Cutcher-Gershenfeld 1994). Typically there is an explicit negotiation on ground rules, meeting logistics, and the overall approach at the beginning of a formal negotiation. At the institutional level of analysis the rules of the game for interactions are just as important and represent a negotiated order, though the process by which they are established or modified, outside of some formal settings like public international law, is often less explicit.

Embedded in the key interests in Table One that are “at stake” are potential changes in the “rules of the game” for interactions in science. Many of the core rules in science, such as protection of intellectual property and company valuations in the commercial sector and competitive double-blind peer review of articles and peer-review panels for NSF and NIH grants in the academic sector, position science as the product of a succession of competitive contests with supporting rules for the contests. While these rules have the stated aim of promoting innovation, they can have the opposite effect—rewarding only that which fits into established models. The COVID-19 pandemic includes two contrasting possible departures from these rules of the game representing potential new negotiated orders.

One departure from existing rules of the game would be in the direction of increased collaboration and sharing, with credit being widely distributed. Here the alternative logic centers on science becoming more of a shared enterprise, motivated by the intrinsic importance of making progress against the pathogen.

The US National Science Foundation (NSF) responded quickly to the need for COVID research by awarding more than 760 individual Rapid Response Research (RAPID) grant awards early in 2020. In doing so, many of the rules governing new submissions and existing grants were relaxed, allowing substantial flexibility for program officers. In many ways, however, this move was merely an acceleration of long-standing agency efforts to foster increased collaboration and open sharing in science. The NSF began enforcing a requirement for data management plans that address data sharing in 2011 and began funding Research Coordination Networks in 2000. The NSF has had earlier programs on shared data and computational and experimental resources, and continues to support a range of approaches to sharing scientific data. In 2015 the NSF funded four Big Data Innovation Hubs (BD Hubs), one in each of the four Census Regions of the United States—Midwest, Northeast, South, and West—that are directly engaging the issue of collaboration. The challenge is considerable, as one BD Hub leader commented:

There are so many silos everywhere: businesses are siloed. Academic institutions are families. Everybody's siloed. Communities are siloed. It's when you work together that you

can get more done right. What do they say: “go fast, go alone; go far, go together.”

Health-related big data collaboration is important, but seen as hard to do. Before the pandemic, in a 2019 stakeholder survey of sixty-nine regional leaders working with the West BD Hub, “applications of big data to advance precision medicine, including diagnostics, treatment, genomics and understanding about environmental exposures” was one of the top five (out of sixteen) most important issues and the one rated as the most difficult to make progress on (West Big Data Innovation Hub Stakeholder Alignment Report 2019). This challenge became very real when, in July, 2020, BD Hubs launched the COVID Information Commons, a web-based portal for filtered search of the NSF COVID RAPID grants that enables researchers to connect. As the BD Hubs leader commented:

So what we’ve been trying to do is find places that we can aim them [researchers] at each other and team them up together. ... The COVID Information Commons is an example.

Pointing researchers toward one another is important, though it doesn’t fully address all the relevant rules of the game. The BD Hub Leader noted:

Researchers are incentivized to do a great job all by themselves. That’s how they’ve always been incentivized. When you get tenure....When you get an award. It’s your award. Or you’re connected by your domain area....What we’re trying to do now is more integrated, multi-disciplinary convergence research.

This same kind of integrated, multidisciplinary convergence pandemic research was lifted up in a highly visible way in a May 1, 2020, letter in the journal *Science*, calling for the open sharing of pandemic models. The letter stated, “At this time of crisis, it is more important than ever for scientists around the world to openly share their knowledge, expertise, tools, and technology” (Barton et al. 2020) The thirty coauthors further stated that “presenting modeling results alone is not enough. Scientists must also openly share their model code so that the results can be replicated and evaluated.” The coauthors rejected proprietary approaches and emphasized what are called the “FAIR” data principles (data that is findable, accessible, interoperable, and reusable), concluding: “Proprietary black boxes and code withheld for competitive motivations have no place in the global crisis we face today. As soon as

possible, please place your code in a trusted digital repository so that it is findable, accessible, interoperable, and reusable.”

The letter itself represents a move in the ongoing renegotiation of the institutional order and an attempt to move the field from “They can’t do that” to “We do that.” We contacted the lead author on the *Science* letter, Michael Barton, a professor at Arizona State University, to better understand how this move came about. He noted that the first draft began with “a small existing network of folks who had been collaborating for a while.” As each shared with their respective networks what they were doing, others asked to join in. Then the full group ran into a small, but emblematic institutional barrier that was removed through negotiation. The journal only wanted to list the coauthors with their university affiliations, but, Michael noted, “many were leading organizations [in addition to their university roles] and we felt that listing their additional affiliations would have a greater impact. There was resistance and it took our editor going to bat for us. Not only was she ultimately successful, but she also came back with an agreement to make the letter open access.” The publishing norm of tying individuals solely to their university affiliations, rather than multiple other roles, is part of maintaining the existing order and arguably could be indicative of the iron law of oligarchy. In granting the exception, a hint of a new pattern is indicated, in which collaboration and multiple affiliations can be signaled by scholars.

Of course there are broader issues for scientific publishing rooted in proprietary views of scholarly articles, reflected in paywalls to get access and challenges to publishers’ business models posed by open access policies. In this context, the publisher of this journal, Wiley, has established an open Coronavirus Hub making all COVID-related published work across its portfolio of journals free to read. That has had over 360,000 page views and there have been an additional 6.7 million article views through Wiley Online Library. Here the rules of the game (publisher paywalls) have been suspended in a crisis. It remains to be seen if there will be similar hubs generated for other emergent societal challenges and how long they will persist in each case.

A contrasting departure from existing rules of the game would be in the direction of decreased collaboration and sharing. We have begun interviewing scientists on the sharing of COVID-19 models. The modeling of disease is a domain that is more on the side of open sharing relative to other fields, disciplines, and domains in science and social science. There are still types of data that can’t or shouldn’t be shared in this domain, but there are common methods, standardization, and a dependence on common resources, such as high performance computing for modeling, that enable and drive collaboration around data. As

a result, we were surprised to hear preliminary reports that the usual patterns of sharing data and collaborating have been disrupted in a negative way. In this case, the disruption is due both to the biology of the virus, which takes time to fully understand and has caused many labs to be shuttered or diverted from ongoing work to new COVID-19 related projects, as well as the contemporaneous political environment. As described by a scientist active in COVID response research, “We have a perfect storm politically and biologically.”

The politicization of the pandemic seems particularly chilling to efforts by scientists to develop an effective response in the US, and also negatively affects the potential for coordination at all levels, particularly at the international level. The US intention to pull out of WHO undermines the ability to share data and models internationally, to improve modeling of the epidemic, and to formulate coordinated responses. Further, the uncertainty created by the lack of understanding of COVID-19 pathogenesis and the politicization of the situation inhibit data collection, data sharing, and epidemiological model development.

However, in this ongoing renegotiation of the prevailing order there are additional positive forces that support accelerated sharing. Initial interviews suggest that the increased data sharing expectations that developed in the wake of the 2014–2016 Ebola crisis continue, are growing in the context of COVID-19, and are likely to persist. Individuals, groups, and organizations are pivoting and making contributions to the COVID response. Fortunately, the 2003 SARS epidemic did not become a pandemic. However, the fact that it did not reach pandemic state led to some resultant complacency in overall pandemic preparedness. The current situation, respondents noted, has the potential to reinvigorate US planning and capacity building for the next pandemic.

Consistent with the call for open pandemic models, there are dozens of open source initiatives in response to the pandemic. For example, the NIH lists twenty-eight open source data initiatives, along with another four open source computational resource initiatives, and another eleven additional supporting open source resources (NIH 2020b). These are all illustrative of a collaborative negotiated order with sharing baked into the rules of the game. Many of the groups listed, such as the Protein Data Bank, PubMed Central, PubChem, Open ICPSR, the XSEDE high performance computing initiative, and the Research Data Alliance, have long been leaders in advancing open data in science. Others, such as the AWS data lake and the Google Cloud Platform, are commercial players operating based on a competitive market-based approach, but have carved out open source collaborative initiatives. They may be doing so out of goodwill in a crisis, though they also likely have an interest in

staying at the forefront of innovation and in the continuing survival of their organizations (as predicted by the iron law of oligarchy).

Another response to COVID-19 centers around prizes and competitions, which represent an interesting blend of collaboration and competition. Being the first has the logic of a “prize” model and is all about demonstrated impact, which is not inconsistent with some aspects of collaboration, but brings an additional competitive logic. Interestingly, on the same day as the letter calling for open pandemic models in *Science* (May 1, 2020), Nobel Prize economist Paul Romer was featured in *The Times Higher Education* (which publishes the World University Rankings) stating: “Offering a £1 billion prize to the university or research group that created a mass test would be far more effective than trying to coordinate research internationally” (Grove 2020). Here the competitive logic of a prize is offered as different and—Romer argues—more likely to be effective compared to coordination and collaboration.

There are certainly many dozens of COVID-19 competitions now in play, though none that we have seen has prizes equivalent to the £1 billion that Paul Romer has called for. These are mostly what are termed “inducement” prizes rather than “recognition” prizes, such as the Nobel Prize (National Academy of Engineering 1999; Kalil 2006). The Stanton Foundation has announced a series of weekly \$1,000 recognition prizes for already published articles “Applying History to Clarify the COVID-19 Challenge,” followed by a \$2,500 grand prize (Stanton Foundation 2020). The prizes may also have the intent to serve as an inducement for additional scholarship. The American Heart Association, Hitachi, and BurstIQ have announced a \$45,000 “COVID-19 Data Challenge,” which is an inducement prize to examine the relationships between COVID-19, other health conditions, health disparities, and/or social determinants of health (AHA 2020). The IndieBio Coronavirus Initiative is seeking up to eight start-ups to receive a minimum of \$250,000 each to pursue the development of diagnostics, therapeutics, vaccines, disinfection, and other solutions addressing the worldwide problem of emerging infectious diseases—also inducement prizes (IndieBio 2020). The AWS Diagnostic Development Initiative has committed \$20 million over the next year to support AWS customers who are working to bring better, more accurate diagnostic solutions to market faster—again designed to be an inducement (AWS 2020). These are just some examples of the many prizes in play, illustrating a range of funding commitments and foci, with most serving as inducements for new actions that might not otherwise have occurred. These are also all competitions where the focus is on the winners.

The XPRIZE has a long history of being at the intersection of competition and collaboration, which is evident in the following call around the pandemic:

To accelerate the world's response to the greatest challenge we face today, XPRIZE is launching the XPRIZE Pandemic Alliance, powered by the XPRIZE Data Collaborative, a powerful platform for collaboration, combining data, AI tools, and bleeding edge insights and ideas with a community of innovators on the fringe.

Comprised of a collection of exclusive datasets and AI capabilities spanning multiple domains, the XPRIZE Data Collaborative democratizes access to data and the tools needed to develop solutions, thus enabling teams and collaborators to use these valuable assets to solve the world's most immediate challenges. Our goal is to incentivize and capture the collective intelligence and wisdom of the global community to identify and develop solutions based on data, beginning with the global pandemic we face today and extending further within the domains of health, economy, environment, and equity for all. (XPRIZE 2020)

In contrast to prizes that are just focused on inducing innovation through rewards and recognition, there is additional focus with the XPRIZE on sustained collaboration following the award.

As Andrew Tauhert, Vice President, Partnerships and Strategic Engagements for the XPRIZE commented:

This is a means of engaging a community of collaborators both before and after the prize. Even more-so, the thought leaders of the XPRIZE Pandemic Alliance convene and provide input on where we should focus, what an impactful prize could look like, what the parameters/winning criteria of that prize should be to maximize impact. Then, [the Alliance] plays a role in how the prize continues on after it is won and, very importantly, have a hand in the scaling and impact of that prize. For example, the recently launched prizes around Next Generation Masks as well as Rapid COVID Testing both have, as part of the prize, an impact/scaling component. In the case of Next Gen Masks, we are securing commitments from manufacturers to produce the winning design and retailers to distribute them whereas for the Rapid COVID Testing prize, we are including a phase where the winning protocols must be implemented in scale. The Alliance plays a pivotal role in this. The above is made possible by having an engaged Alliance of corporations, NGOs, universities, etc. who can provide the direction and resources to execute on all of these domains.

A blending of competition and collaboration is also illustrated by the COVID-19 Open Research Dataset Challenge (CORD-19), which is an initiative by AI2, CZI, MSR, Georgetown, NIH, and The White House. CORD-19 frames the challenge as follows:

In response to the COVID-19 pandemic, the White House and a coalition of leading research groups have prepared the COVID-19 Open Research Dataset (CORD-19). CORD-19 is a resource of over 181,000 scholarly articles, including over 80,000 with full text, about COVID-19, SARS-CoV-2, and related coronaviruses. This freely available dataset is provided to the global research community to apply recent advances in natural language processing and other AI techniques to generate new insights in support of the ongoing fight against this infectious disease. (Kaggle 2020)

CORD-19 is an open access compilation of data sets, which is collaborative, but it is organized as a series of challenges, each with evaluation criteria and winners. One of the partners, Kaggle, is sponsoring a \$1,000 per task award (there are seventeen tasks listed) for the submission that is identified as best meeting the evaluation criteria. They also note that “the winner may elect to receive this award as a charitable donation to COVID-19 relief/research efforts or as a monetary payment,” suggesting that the recognition and impact may be more important than the monetary prize.

Getting the rules of the game right for a competition is hard to do and essential (Ubois and Kalil 2019). We highlight here the importance of attending to both competition and collaboration in these rules of the game. Further, the emphasis on competition and cooperation doesn’t happen in a vacuum—it is interpreted against the relevant research cultural context.

It is hard for the organizers of contests to embrace emergent institutional innovation since contest criteria typically emphasize certainty in delivering on the promise. Consider the July 20, 2020, announcement by the MacArthur Foundation of the six finalists in its “100 and Change” competition. While the competition was launched in April, 2019, nearly a year before the pandemic, the results are instructive in this context. Two of the finalists for the \$100 million prize are established entities such as the Clinton Health Access Initiative and the National Geographic Pristine Seas Initiative. There are also what look to be more grassroots movements focused on eliminating news deserts and eradicating mosquito-borne diseases. The forces of the iron law of oligarchy will pull the Foundation toward more established winners, while Elinor Ostrom’s call for institutional innovation will pull toward nontraditional

arrangements. A third option, which we highlight here, would be contests to launch pre-competitive partnerships that then provide a constructive institutional space within which collaborative innovation can be fostered. This, of course, involves very different rules of the game.

The University of Virginia (UVA) provides an instructive illustration of a COVID-19-related pivot involving a mix of success and limitations in changing the rules of the game around enabling data sharing without a competition. Before the pandemic, in October, 2019, the University was awarded an NSF Major Research Instrumentation grant to create computational infrastructure for hosting protected data that would be made available to the other public universities in the Commonwealth of Virginia. Although some of the universities in the Commonwealth already had computational resources for hosting protected health data (PHI) and data from federal agencies (Controlled Unclassified Information or CUI), most of the mid-size and smaller universities did not. Beyond the large, expected sources of new ideas in science (large research universities, laboratories, etc.), researchers at smaller universities have a strong likelihood of also doing great research. However, without infrastructure that is approved to host protected data, these researchers cannot collect data, much less analyze it. The Virginia ACCORD project was created to foster collaboration in ways that would overcome the limits of the rules governing research data. As a shared infrastructure, the project was possible since all the public universities are legally organized under the Virginia Attorney General (AG), so issues of liability and risk were simplified since they could be approached by treating the campuses as a single entity for this purpose. The pandemic heightened the importance of this shared infrastructure, since much of the relevant research data was PHI and CUI, often with high-performance compute requirements. All being in the same state was a benefit in this process.

As the ACCORD project emphasized COVID-19 data support, a challenge arose, which was that the relevant collaboration did not stop at the state border. As a result, early in the course of the pandemic, UVA approached the NSF about the possibility of expanding the scope of the ACCORD award to include COVID-19 data research by researchers at other universities outside the Commonwealth. Through some accelerated negotiations, a supplemental award was made to support this additional goal. Though the funding was awarded for this function, the complexities of going outside the Commonwealth to support research are significant. Rules for risk and liability assignment, matching of controls for compliance, documentation of compliance, and other important aspects of protecting data have had to be negotiated and worked through. The complexity has been multiplied by the fact that different agencies and different data types require meeting different compliance

rulesets. In some cases, the inability to renegotiate the conflicting rules of the game associated with this forum has been an insurmountable barrier—leading collaborative opportunities to be abandoned. At the same time, there are instances of COVID-related data sharing that have crossed state lines and utilized the ACCORD infrastructure, revealing both the limits and the potential for more agile institutional arrangements.

Paying attention to these various exemplar rules of the game is important. The competitions represent a magnification of already existing proprietary and competitive norms in the form of explicit contests. They are also short-lived and less likely to produce enduring institutional change. Competitive contests are less likely to be disruptive to the negotiated order as they don't undercut the dominant institutional norms in the private sector, in universities, and in government agencies. In the long term, contests risk becoming tragedies of the commons if the winners are not required to collaborate on a continuing basis. Here there is the risk of temporary collaboration and a snap-back.

In this initial look at COVID-19 pandemic effects on the rules of the game we see three early patterns. First, there is some evidence indicating that the prior calls for open sharing of data and increased collaboration have intensified in the crisis. Second, unexpectedly, domains with strong traditions of sharing and collaboration are actually experiencing restraints on sharing due to the complicated nature of the pathogen, as well as the chilling influence of polarization and politics in US society. Third, there is wide use of contests that are responsive in a crisis, but represent a time-bound response that is less disruptive of the negotiated order compared to forging ongoing collaborative arrangements.

One key factor impacting the potential for ongoing collaborative arrangements concerns the degree to which they are instantiated with forums that can maintain a new negotiated order. This is where the value of carving out pre-competitive spaces is promising. Establishing these types of forums (often with some type of charter) is a form of institutionalization to which we now turn.

Forums Present and Absent

While there are no explicit forums for negotiation over high-level institutional norms around collaboration or competition with COVID-19 data, models, and resources, there are forums—such as Ostrom's "action arenas"—within which relevant interactions (collaboration or competition) do take place. These include digital platforms for sharing, data repositories, consortia, webinars, policy pronouncements, social networks, and others. Of course the pandemic makes some forums more complicated since face-to-face interactions are limited. As well, there are what are

termed “structural holes” or gaps in the institutional arrangements (Burt 1992) where forums are missing.

Many established forums have pivoted to focus on the sharing of data, models, and resources that address the COVID-19 pandemic, with some initial evidence of accelerated results. As the Organization for Economic Cooperation and Development (OECD) noted in a May 12, 2020, posting:

The full genome of COVID-19 was published barely a month after the first patient was admitted into Wuhan hospital, as an open-access publication in *The Lancet*. This is to be compared with a five-month delay in the case of SARS outbreak in 2002–03, a large part of this delay being due to an information blackout in the first months of the SARS epidemic (OECD 2020).

The OECD went on to note the many pledges from journals, government agencies, researchers, and commercial organizations to take an open approach to the pandemic:

In January 2020, 117 organisations—including journals, funding bodies, and centres for disease prevention—signed a statement titled “Sharing research data and findings relevant to the novel coronavirus outbreak”, committing to provide immediate open access for peer-reviewed publications at least for the duration of the outbreak, to make research findings available via preprint servers, and to share results immediately with the World Health Organization (WHO). This was followed in March by the Public Health Emergency COVID-19 Initiative, launched by 12 countries at the level of chief science advisors or equivalent, calling for open access to publications and machine-readable access to data related to COVID-19, which resulted in an even stronger commitment by publishers.

The Open COVID Pledge was launched in April 2020 by an international coalition of scientists, lawyers, and technology companies, and calls on authors to make all intellectual property (IP) under their control available, free of charge, and without encumbrances to help end the COVID-19 pandemic, and reduce the impact of the disease. Some notable signatories include Intel, Facebook, Amazon, IBM, Sandia National Laboratories, Hewlett Packard, Microsoft, Uber, Open Knowledge Foundation, the Massachusetts Institute of Technology, and ATandT. The signatories will offer a specific non-exclusive royalty-free Open COVID license to use IP for the purpose of diagnosing, preventing and treating COVID-19.

In this context, as we noted earlier, the U.S. National Science Foundation offered the opportunity for funded PIs to meet with their program officers in order to refocus their efforts around COVID-19. Similarly, the U.S. Centers for Disease Control and Prevention refocused their existing web presence on COVID-19. Given the severity of the pandemic, organizations that did not respond faced possible negative repercussions. In this sense, these efforts are consistent with the iron law of oligarchy. While some internal negotiations were needed on the specifics of these efforts in existing forums, we look forward to learning if there was any disagreement with the overall strategy and approach, particularly around efforts to move beyond what might be considered a short-term or limited form of engagement.

In other cases, where there were not adequate forums, new forums and initiatives have been set up. For example, the European Commission worked with partners to establish a new COVID-19 data portal in April 2020 for sharing research data. Similarly, the Research Data Alliance (RDA) set up a COVID-19 Working Group and also joined with the Committee on Data (CODATA) and the World Data System of the International Science Council (ISC) along with Go FAIR to form “Data Together COVID-19 Appeal and Actions” (CODATA 2020). The first two initiatives under Data Together are: Data Together–GO FAIR Virus Outbreak Data Network (VODAN) and the RDA COVID-19 Working Group. Here a more extensive negotiation was involved to prepare a recommendation for the United Nations Educational, Scientific and Cultural Organisation (UNESCO) as part of their “Open Science” initiative (UNESCO 2020a). Following on the UNESCO recommendation submitted by the ISC with “open science” framed around “science as a public good” (ISC 2019)—the CODATA Coordinated Expert Group submitted on June 15, 2020 its UNESCO recommendation on “Open Science for a Global Transformation” (UNESCO 2020b). This Data Together recommendation emerged from weekly dialogues after CODATA was alerted on April 29, 2020 about the UNESCO “Open Science” initiative.

Momentum behind the Data Together community for their UNESCO recommendation is reflected by the e-mail thread that emerged on the CODATA list-serve on April 29, 2020, responding to a message from Paul Arthur Berkman:

[I]n view of open science contributing to informed decisions—which operate across a “continuum of urgencies” short-term to long-term—it may be helpful to consider the methodology of informed decision making (following figure). The above methodology with associated skills and theory of informed decision making evolved from 2016 discussions with INGSA and were introduced in *Science* (Berkman et al. 2017) with

subsequent elaboration. Informed decision making is now being trained with the United Nations Institute for Training and Research (UNITAR) as well as with national diplomatic academies, triangulating education, research and leadership with lifelong learning in support of the United Nations Educational, Scientific and Cultural Organization goals.

The thread included ninety-three responses from twenty-eight collaborators through May 10, 2020 (when the CODATA Coordinated Expert Group was formed), involving e-mail commentaries with two adaptations of the associated figure (see Figure 5 in Berkman et al. 2017), an additional model about decision making, and a model about the “data cycle.” These science-community recommendations are contributing to an “inclusive, consultative, responsible and transparent” process to result in a UNESCO Recommendation on Open Science that is scheduled to be adopted at the 41st UNESCO General Conference with its 193 member states in November 2021. In short, we are seeing that an emerging collaborative new order around sharing data and models is negotiated through social networks in an interactive fashion.

In the social sciences and geosciences where the COVID-19 data itself is relatively limited, there have been increases in data submissions and data requests to data facilities, one type of forum, during the pandemic. This reflects field researchers who are more limited in conducting fieldwork and are turning to repositories and teaching that increasingly include online labs and exercises calling on available digital data (Diggs 2020). This also reflects relatively recent journal requirements (rules of the game in another type of forum) for findable and reusable data submissions with articles (no longer accepting data supplements as PDF files that are not reusable). Some of the increase in volume for data facilities may decline as fieldwork opens up, but some of the pandemic patterns may continue at a higher level following the inflection point.

There are considerable challenges around standardization, interoperability, systems integration, and shared governance associated with the sharing of data and models relevant to COVID-19 and broader sharing of data and models in many fields, disciplines, and domains. Complex as these challenges with digital objects are, the challenges are even more complex with forums that also deal with physical resources, such as designs for personal protective equipment (PPE) and the actual production of PPE. With the breakdown of global supply chains, we find that virtual research and development (R&D) forums and virtual production networks have emerged in response to the COVID-19 pandemic.

In May, 2020, a virtual R&D forum emerged at MIT’s Center for Bits and Atoms (CBA), led by Neil Gershenfeld and focusing on research to

support rapid-prototyping responses to the pandemic. This forum grew to a group of over 200 experts participating in weekly online video sessions exploring the underlying science needed for COVID resource sharing (Cutcher-Gershenfeld, Gershenfeld, and Gershenfeld 2021 forthcoming). For example, many DIY PPE shields were open on all sides, but individuals in this group used computational fluid dynamic modeling to demonstrate the importance of sealing those surfaces. This was then followed by the development of designs for cutting and folding clear plastic sheets (using kirigami) to eliminate 3D-printed holders, and using the mathematics of curved creases to create continuous contours.

To illustrate the nature of interactions in this forum, here is an example of an individual posing a question for the community (with names removed):

We believe that we have [a] process for predicting the pressure drop and filter efficiency of different filter materials based on 3D scanned geometry of the filter. However, we require a sample of geometry with known properties to test this capability. The 3D data can be a CT scan or other grey/black and white images series. would you be able to get this?

Here is an example of offering things up to the community:

Hi. If any of you have swabs and want to test them, we are happy to test them and post here the results. So far, we have got 2 different companies providing us multiple versions of their swabs.

As these selected comments indicate, the interactions were collaborative with a strong tone centered on goodwill, courtesy, and mutual interest. Indeed, in reflecting on the forum, Neil Gershenfeld noted that all sides appreciated collaborating with people they had never considered to be relevant or approachable. He also noted that all the relevant information is publicly available on GitHub (Coronavirus tracking project for rapid-prototyping response 2020).

After weekly one-hour sessions in April and May, the group shifted in June to biweekly meetings and, in July, is operating on demand. So far, the schedule is still filling every other week, but this pattern suggests a trajectory that will slow down as the focus shifts away from needed R&D and as the participants return to other parts of their research agenda.

A more formal forum for the sharing of designs and resources has been the Open Source Medical Supplies organization (OSMS 2020). By sharing designs, models, best practices, and processes, OSMS is helping

support over 750 local response groups in 55 countries. A project of the NGO RESOLVE, OSMS was founded in March 2020 and quickly grew into a global network of 70,000 makers, fabricators, community organizers, and medical professionals. Their Facebook page served as a communication platform, and their project library of over one hundred PPE designs served as a reference point for local design and production. While OSMS does not assume any liability for project designs, and states explicitly that they are not certified by any national regulatory agency, interviewees mobilizing local production efforts viewed them as a source of authority in the ecosystem. Here the existing negotiated order, which includes issues of liability, legitimacy, and regulatory compliance, is being sidestepped temporarily, but it may not be a viable arrangement in the long run.

Complementing these emerging, virtual R&D initiatives at MIT and OSMS have been local and regional virtual production networks. These involve fab labs, makerspaces, and entrepreneurial businesses with rapid prototyping equipment. When the pandemic emerged, Martina Francesca Ferracane was in Boston, having traveled from Italy, participating in the Fab Academy. She was there to learn essential skills needed in a fab lab she had launched in Sicily. As news arrived about the crisis back in Italy, she immediately returned home and began to coordinate production of personal protective equipment (PPE) among all fab labs in Sicily since the global supply chain for this equipment had broken down. She recalled, “We began by talking with hospitals to find out what was needed. Then we identified designs that had been validated and placed them in a shared folder.” Ferracane noted that the fab labs had no experience with the right thicknesses of the clear plastic materials or the ways to ensure that they were properly sterilized. These issues were addressed in a highly collaborative manner and the network of fab labs was able to deliver over 3,000 face masks to local hospitals. The network joined the national coordination movement that also started in parallel. The national network was able to innovate further on existing designs. For example, starting with a validated design for an intubation box (a clear plastic protector for the upper torso during intubation so the doctor can use attached gloves and avoid infection in what otherwise is a highly risky procedure), they adapted the design for different sizes of intubation tools and hospital beds. When supply chains for breathing valves for ventilators broke down, a commercial rapid prototyping facility responded within six hours with the needed spare parts (Zarzalejos and Moynihan 2020). In these cases, collaboration and sharing emerged quickly and effectively.

More challenging for the Italian fab labs were regulatory matters. Ferracane reports that she had planned to reach out to regional and

national regulatory officials, but she was told not to ask because they would have been told to stop. The company Isinnova, which created hundreds of adaptors to transform snorkeling masks into respirators of last resort, had even received a formal request by the Ministry for Health to take down the website with the open file for the 3D printing production of the adaptors. At the local level, she says, “it was easier to be in touch with people” and the need was clear since supply chains had broken down. Uses of the PPE outside of health care by, for example, Italian sanitation workers did not raise the same liability issues. Still, the labs were worried about liability associated with medical use (where the same PPE automatically became a medical device), so they prepared a disclaimer. At first, the conflicting interests around liability looked to be a barrier when hospital officials worried about signing the disclaimer. The issue was resolved when a doctor in the hospital agreed to assume liability, signed the disclaimer, and then personally distributed the materials. This negotiation over liability illustrates both the limits of the existing social order, the lack of established protocols to guide new, needed interactions, and the essential roles of leadership and goodwill among all involved.

Looking ahead, Ferracane believes that “the main change because of COVID will be a system that is more structured and that has more communication. In the future, there will be more knowledge on what is available and we will be able to respond more quickly in a crisis.” Remaining to be seen, however, is how the system will be more structured. Each fab lab is a relatively autonomous organization. They are now bound together in a loose network sometimes described as a decentralized or polycentric network (Ostrom 2008), but Ferracane reported that there is no established way to select leaders, make decisions, or address other operational matters if the network is to continue as a virtual organization. Resolving these matters will be a negotiated process with issues of autonomy, on the one hand, and collective impact on the other.

A similar example of local production networks took place in the California Bay Area, where a regional ecosystem of fab labs, community makerspaces, and small businesses and manufacturers emerged to produce PPE. In the early days of the pandemic, Danny Beesley, founder and principal of Idea Builder Labs, played a negotiating role in the community in helping people to use best practices and models. A common issue in locally producing face shields was the number of disparate designs. Beesley “triangulated” between various approaches and found the best designs and most efficient processes for making them, which he then disseminated. He then tried to address the main problems everyone was facing in local PPE production: “who pays for it and where do you get your materials from.” He recalls, “For about a three-week period

you couldn't get cheap plastic anywhere in the country." If he could solve these challenges, "Everyone who had machines could just focus on production." Beesley identified a disused factory space and offered it as a distribution and logistics hub with the ability to receive, process, and disseminate materials for the local region. Upon advertising this through his networks, he was contacted by someone with connections to the Coca-Cola Company who had access to plastics appropriate for face shields through their supply chain. They negotiated tons of plastic being sent to Beesley's facility, creating a materials-sourcing hub for local lab production.

The responsiveness to the crisis speaks to Beesley's boundary-spanning role in the regional ecosystem. Beesley noted that he felt like "he was the most prepared person" for the pandemic, a sentiment that speaks to the preexisting capacity in the network of local production hubs in the region. Indeed, the network of fab labs is now in the process of converting into a worker-owned cooperative—adopting an institutional form that is more formal than the current network, but still consistent with its collaborative ethos. However, with COVID rates continuing to increase in the region, Beesley sees demand for PPE continuing, with bottlenecks of access to financial capital, and the increasing risk of burnout as the crisis continues to demand volunteer time and energy. Sustaining local networks of production is therefore a challenge in the absence of core funding models for their services.

While institutional support and resources have not been forthcoming, Beesley sees a growing shift in perspectives toward the importance of local manufacturing, including production capacity and sourcing of local materials. Institutions such as the local economic development board have "entirely shifted their focus from an economic development standpoint. Manufacturing is the number one thing for them now." Beesley is now helping to develop policy recommendations around local procurement. While local government has preferential purchasing policies for small and medium-sized enterprises and minority-owned businesses, Beesley seeks to expand these policies to give preference for local producing and local sourcing. If governmental entities adopt these purchasing policies, they can become a driver for local manufacturing. As Beesley stated, "If our system has failed to the point that we can't produce the things that save our own lives...you need to realize that there is some evolution that is needed."

While the sharing of information in the virtual R&D meetings at MIT may not persist in its current form following the pandemic, it is clear that the virtual production network in California is focusing on transitioning into a sustainable model. In doing so, they are employing what is for them a new institutional arrangement—a worker-owned

cooperative—rather than a loosely connected network of fab labs. In this sense, it is less a matter of continually negotiating collaboration since participants will be operating in a context designed with cooperation as its defining feature. It remains to be seen how this new worker-owned cooperative will navigate the iron law of oligarchy as it becomes more formal.

None of the collaborative arrangements that we have documented here are yet formalized to the degree of a pre-competitive partnership such as the BioMarkers Consortium, noted earlier (Knight, Cutcher-Gershenfeld, and Mittleman 2015). It took multiple years for groups of leaders and lawyers from government, academia, civil society, industry, and government to establish the protocols needed to carve out a pre-competitive space that would not violate anti-trust laws, improperly delegate government authority, and otherwise advance the interests of the diverse stakeholders without unacceptable risks for all parties. It is possible, however, that some of the collaborative forums that have emerged in the current crisis provide clues for more agile methods of launching and sustaining pre-competitive partnerships.

Limitations

This is a preliminary report on continuing research, which limits our findings in two ways. First, the data already collected will be subject to continuing analysis and, second, new insights will emerge as events and data collection both continue to unfold. Given the magnitude of the pandemic and the urgency of navigating the issues, we felt compelled to offer these preliminary observations, but caution is urged given the dynamic nature of events.

A further limitation is the current lack of systematic stakeholder survey data to triangulate with the interview data. Such a survey is contemplated, but not yet conducted. We look forward to adding that to the research in the months to come—to speak with greater confidence on the stakeholders, interests, rules of the game, and forums (present and absent).

Conclusion

COVID-19 and the concurrent economic and social impacts on society are a disruptive force with long-term implications. For the science enterprise, deeply embedded norms within the negotiated order are now “on the table” for renegotiation. In this early report on our research we find a complex mix of institutional dynamics. Some institutional arrangements centered on the open sharing of data, models, and resources have been accelerated, at least for the short term. At the same

time the complexity of the virus itself and the political overlay around the response to the pandemic have restrained open sharing and collaboration. Concurrently, competitive norms have been reinforced with the announcement of prizes and contests, with some of the contests also incentivizing collaboration. Existing organizations are taking actions to ensure their continued existence as predicted by the iron law of oligarchy. New, emerging organizations face the challenge of becoming captive to this iron law as existing institutions may co-opt their efforts.

It is too soon to know whether the emergent re-negotiated rules of the game will center on a long-term increase in collaboration and sharing, or whether we will see a snap-back to the pre-pandemic negotiated order (perhaps building on competitive “winner-take-all” contests). It is too soon to know if the transformation of existing forums and the emergence of new ones will be a short-term or long-term development. What we can say for certain at this stage, is that how the responses to the pandemic are framed and structured needs careful consideration. Framing the response as collaborative or competitive does matter. Ensuring that there are effective forums, particularly virtual forums, also matters.

There are clear successes, such as the accelerated sequencing of the genome for the virus. There are also unexpected promising developments such as the emergence of virtual R&D forums and distributed fab lab production networks for PPE and other needed resources. Much of the collaboration with data, models, and resources has been without formal contracts and other long-term institutional arrangements. Goodwill, extensive communication, and the harnessing of multi-stakeholder consortia have enabled progress in what are most likely still the early stages of the pandemic. We have not yet hit an inflection point that would represent entry into a period of reduced spread (globally) and recovery. At this stage, however, our analysis points to a key set of opportunities and a key set of threats.

The opportunities before us are to lean in during the crisis and build the new, collaborative, more open institutional arrangements that we would like to see going forward. It will be a complex negotiated process, with many stakeholders and many interests “at stake,” spanning patients, their families, communities experiencing increased disparities, health-care providers, researchers, commercial enterprises, government agencies, data professionals, publishers, and others including the public at large. Not all will have a seat “at the table,” but all have interests that need to be taken into account. Wise choices about framing the issues and early repeated patterns of interaction hold promise for the future. In the case of collaboration and the sharing of data, models, and resources, now is the time to go beyond pronouncements, initiatives, and even actual sharing. It is a time to codify understandings, charter long-term

forums, and otherwise invest in the institutional infrastructure needed for science that is more open and more collaborative. Clear rules of the game for launching and sustaining pre-competitive partnerships will be key to fostering collaboration across public, private, and university settings. Using the language of negotiation theory, this will be a more integrative, problem-solving process, even if there will be some distributive challenges if we are to move from “They can’t do that” to “We do that.”

The risks before us center on the iron law of oligarchy and tragedies of the commons driving a snap-back to the way things were or, worse still, to increased polarization and division. The pandemic has revealed disparities while also sharpening divides in civil society. For the most part, leaders in a diverse array of scientific fields, disciplines, and domains have sought high ground with town halls, reflective commentaries, and policy initiatives. But it will not be easy to root out the deeply embedded assumptions that scientific progress depends on competition, the hiring of superstars, the protection of intellectual property, the triumphant winner-take-all contests, and other norms, practices, and assumptions of the current negotiated order—arrangements that undermine collaboration and open sharing. Again using the language of negotiation theory, wrestling with these embedded competitive, proprietary, and individualistic aspects of the science enterprise will be a more distributive process that will require hard bargaining, even if there will be some integrative mutual interests involved.

During the pandemic many more scientific fields, disciplines, and domains have moved beyond “They can’t do that.” and “Are they doing that?” to “Can we do that?” It is now a much bigger step across many fields and disciplines to “We do that.” This article poses the core question, which is whether “We do that.” is temporary or enduring. The rules of the game are changing in supportive ways, but the needed forums and other mechanisms are still emerging. There are powerful institutional forces that will make it difficult for there to be a transformation into a more open form of science following the pandemic, but there is also the potential for this to happen. If it is to happen, now is the time to be renegotiating the negotiated order.

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