15 Conclusion

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KNOWLEDGE AND INNOVATION, on the one hand, and openness and commons, on the other hand, have captured imaginations and investments in both public and private sectors over the last couple of decades, leading to considerable enthusiasm for *knowledge commons*. That enthusiasm has yet to translate into well-grounded principles for the design and deployment of commons governance in knowledge and innovation settings. Building a foundation for such principles is the primary goal of this book and of the research that we hope will come next. In this concluding chapter, we set the first part of that foundation in place by describing the substantive lessons and themes that we derive from the research shared here.

Understanding how knowledge commons are and should be organized and managed is critical both to the design of effective commons approaches and to effective innovation law and public policies. We suspect that knowledge commons governance can and does play a role at least as important as intellectual property law in overcoming the social

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dilemmas that can impede innovation, creative work, and the productive development, distribution, and uses of knowledge. The primary challenge to proving, disproving, or refining that hypothesis is the paucity of systematic empirical work directed to it. What factors contribute to knowledge commons durability and effectiveness?

Answering that question requires detailed analysis and comparison of many different knowledge commons cases. To derive general insights from those cases, the empirical approach must balance structured inquiry with interpretive flexibility. The framework approach applied in this book recognizes the complexity of the interplay among the characteristics of particular resources, various communities and groups, and the social, political, economic, and institutional attributes of governance. It helps researchers to walk the difficult line between overly simplistic theoretical models and a fragmented collection of diverse, one-off studies. It imposes methodological structure and produces findings that can be used in conjunction with and interpreted using theoretical perspectives from a variety of disciplines, including law, economics, sociology, political science, and history.

As discussed in detail in Chapter 1, we pursue this balance by adapting the Institutional Analysis and Development (IAD) research framework, which was used originally to structure case studies of natural resource commons (Ostrom 2005). The IAD framework ensures that each study collects information about a common set of variables, including the biophysical characteristics of the resources involved, the attributes and roles of participants, and the effective "rules-in-use" of the commons regime. The IAD framework permitted data from a large number of case studies to be aggregated systematically and used to derive generally applicable "design principles" for natural resource commons governance.

Our knowledge commons case study framework accounts for significant differences between the natural resource and knowledge contexts. The resources are different, and the obstacles that must be overcome to produce sustainable sharing are different. Knowledge commons generally manage production and integration of new knowledge in addition to managing the use of existing knowledge resources. As a result, knowledge commons address a more varied array of social dilemmas than natural resource commons do. Participation in a knowledge commons may be driven by a variety of self-interested, altruistic, personal, and social motivations. Even the legal delineation of intellectual and knowledge resources is complex. For example, copyright law's definition of what constitutes the "expression" in the copyrightable work governed by open source software licenses is not straightforward. Knowledge commons may confront complicated resource boundary and corresponding resource management issues with respect to what resources are governed by formal legal rights and what resources are part of the public domain.

Chapter 1 (building on Madison, Frischmann, & Strandburg 2010) analyzes these and other differences and explains why they require a framework specifically tailored to knowledge commons. Developing an effective research framework for knowledge commons case studies is, like knowledge governance itself, an unavoidably iterative process. Though structured methodology is crucial to cross-case-study comparison, it is also

important, particularly at this early stage of knowledge commons study, to adapt and revise the framework in response to experience in applying it to a variety of cases.

This book is an early step toward a systematic, framework-driven study of knowledge commons governance. It is much too early to derive design principles from the eleven cases presented here or to suggest general lessons about commons governance. More study is needed. These cases illustrate the potential of the structured case study approach. They also suggest refinements and improvements to the research framework. Despite the diversity of the cases, we identify several key themes common to many of them. Readers may observe different themes. As further studies accumulate, we hope that these observations will develop into more specific hypotheses and, eventually, into useful principles.

I. Emerging Themes

1. Knowledge commons may confront diverse obstacles or social dilemmas, many of which are not well described or reducible to the simple free rider dilemma

Probing the "goals and objectives" of a commons often began with a general notion of cooperation to solve some generic collective action problem, but closer analysis of relevant obstacles tended to reveal multiple dilemmas that shaped action arenas and created demand for governance institutions. Almost all of the knowledge commons described in this book responded to needs both to manage existing knowledge resources and to sustain production of and contribution to a shared knowledge pool. But to stop there would be to miss the forest (or worse, the complex ecosystem) for the trees. Most of the case studies faced multiple additional social dilemmas, including:

- *Dilemmas attributable to the nature of the research and/or the research problem.* In the Urea Cycle Disorders Consortium (UCDC) case study, Strandburg, Frischmann, and Cui (Chapter 5) concluded that special problems associated with rare diseases (distributed population of patients and researchers; small numbers and the need for shared protocols; scarce inputs such as funding, time, and credit; and recruiting researchers; among others) played a more important role in shaping action arenas and corresponding governance institutions than the more basic public goods framing of "sharing knowledge" would suggest. Similarly, in the case of Galaxy Zoo, Madison (Chapter 6) noted that special problems associated with processing massive amounts of astronomical data and the fact that classifying galaxies was difficult for computers but relatively easy for human beings played a more important role in shaping action arenas and corresponding governance institutions than the public good nature of the classifications or the database of classifications.

- *Dilemmas arising from the interdependence among different constituencies of the knowledge commons.* For example, Strandburg, Frischmann, and Cui (Chapter 5) demonstrated special problems associated with managing multiple communities in connection with the UCDC. Researchers, healthcare professionals, patients and families, government officials, and pharmaceutical companies brought different backgrounds, capacities, expectations, and interests to the collaboration, and as a result, successful cooperation depended, among other things, on governance institutions that enabled trust to be built and maintained. As Contreras (Chapter 4) described, sustaining the genomic data commons depends significantly on reconciling the (sometimes conflicting) interests of multiple stakeholders, including government officials (National Institutes of Health [NIH]), funders, data generators, data users, scientific leaders, data intermediaries, data subjects, and the public.
- *Dilemmas arising from the need to manage rivalrous resources that are necessary inputs into production and use of the shared knowledge resources.* For example, in the UCDC case study, Strandburg, Frischmann, and Cui (Chapter 5) identified various rivalrous resources that gave rise to governance challenges, including funding; attention, time, and labor; and attribution and authorship credit. Daniels (Chapter 14) emphasized throughout his study of Congress the ways in which management of rivalrous resources was critical to the functioning of the commons. He noted that litigation over the meaning of laws created by Congress involved rivalry of interests that could, in a sense, render the law rivalrous. He made a similar argument in discussing the goals and objectives of those involved in the legislative process, suggesting again that both rivalry among interests and competition over rivalrous resources necessary for law making were driving factors.
- *Dilemmas arising from (or mitigated by) the broader systems within which a knowledge commons is nested.* Piper (Chapter 12) provided a detailed account of war as the driving force behind various "commons-based IP approaches" in Canada and the United States. War shaped political, cultural, and economic systems more broadly—for example, by encouraging nationalism and collectivism—and at the same time the practical realities of war set conditions in which sharing various knowledge resources was a necessity or, at least, was perceived to be necessary. " 'Battlefield techniques,' such as medical methods, remain in a commons, in part because of the exigencies of their creation, but also because of the necessity that they be shared in the heat of battle." Free rider and related dilemmas faded in importance, overshadowed by the demands of war. As Piper put it, "Patents had the potential to disrupt chains of command, discipline and order through an external system of reward and remuneration," Commons-based approaches overcame that dilemma.

2. Complex relationships often exist between knowledge commons and the systems within which they operate and/or are nested

Chapter 1's outline of the framework anticipated the importance of describing the background environments that shape the knowledge commons under study. The framework suggested a primary focus on the background legal rights associated with commons resources. We did not anticipate fully how broader background contexts would influence the shape of commons governance and/or interact with other framework inquiries. In some cases, the background contexts seemed to act as external constraints much as the biophysical characteristics of the resource do in the natural resource context. In others, background contexts shaped goals and objectives, participants' roles, and action arenas in much more dynamic ways. For example:

- Strandburg, Frischmann, and Cui (Chapter 5) described the UCDC as broadly situated within a context of relatively inflexible "external" constraints consisting of "the biological realities of urea cycle disorders, the cultural contexts of medicine and academic research and the more specific contexts of rare disease research and NIH research funding." The consortium also had a complex relationship with the Rare Disease Clinical Research Network program, since UCDC researchers had important input into the design of that program, within which the UCDC was nested.
- Contreras (Chapter 4) discussed the complex relationships between the NIH and data intermediaries situated between science and industry in the context of the Human Genome Project (HGP). He emphasized how the background context and norms of the scientific community strongly influenced the governance of the HGP and the genomic data commons that have since emerged.
- Shah and Mody (Chapter 9) described the critical and interactive role that knowledge commons play in determining the formation and direction of new industries and in enabling an environment for and complementing market-based entrepreneurship.
- Murray (Chapter 11) described mid-nineteenth-century journalism as a constructed knowledge commons that was part of, rather than antithetical to or subversive of, the market. According to Murray, "Behaviors and priorities associated with commercial markets were actually imbricated with commons."
- Daniels (Chapter 14), who found our call for a discussion of the relevant background environment "very difficult" in his study of Congress as a knowledge commons, explained how Congress is situated within a political environment with significant rivalries and adjacent to a judicial system within which litigation tested and applied the legislation (outputs) from Congress. He also situated Congress within our constitutional framework and historical tradition.

- Piper (Chapter 12) explored the complex relationships between the military, industry, and scientific communities and the role of the NRC technology transfer operations in mediating those relationships and communities.
- Madison (Chapter 6) described Galaxy Zoo as a commons that both extended the norms of the astronomical research community and explicated, drew upon, and reproduced them.

3. KNOWLEDGE COMMONS OFTEN DEPEND ON SHARED INFRASTRUCTURE

Shared infrastructure often appeared to be central to the success of the knowledge commons studied here. In some cases, technical infrastructure appeared to substitute for formal rule-based governance and discipline, easing, though perhaps also obfuscating, decision-making processes.

- Fuster Morell (Chapter 8), in her study of online creation communities, provided the most extensive analysis of the role of shared infrastructure. She suggested that governance of online creation communities can be understood only by paying attention to the infrastructure for collective action. "Infrastructure provision involves [both] the provision of the platform of participation and…control over [various governance institutions]." Based on an empirical study of fifty online creation communities, she reported a correlation between community involvement in infrastructure provision and "a community having a decision-making mechanism, a role in conflict resolution at the community level, deciding its formal rules, a free license that also grants that the community owns the common-pool resource, and net-enabler conditions (including the right to fork)." Critically, Morell's study showed how ownership and/or control of the infrastructure that supports online creation communities (OCCs) may have significant impact on knowledge commons governance.
- Strandburg, Frischmann, and Cui (Chapter 5) emphasized the importance of the Data Management Coordination Center (DMCC) and various research and data management protocols in facilitating knowledge sharing among different clinical research sites. These shared infrastructures lower the costs of participation, collaboration, and research. In addition, the longitudinal study at the heart of the UCDC research agenda serves as a shared infrastructure that forms the community and brings members together and at the same time serves as a platform for other clinical research projects and activities outside of the consortia, including, for example, drug development by pharmaceutical companies.
- Madison (Chapter 6) described the importance of the design of the online interface and access to source image data in making it possible for non-scientists to participate in scientific research and in facilitating the formation of the Galaxy Zoo community. The Galaxy Zoo website, the database of galaxy classifications submitted as "votes" by volunteer classifiers and further analyzed by professional

astronomers, and the Galaxy Zoo forum that sprang up to facilitate supplemental dialogue within the Galaxy Zoo community are three related levels of technical infrastructure that enable cooperation within the volunteer community, within the professional astronomer community, and within the broader group that included both professionals and volunteers.

- Schweik (Chapter 7) noted that the project hosting site, SourceForge.net, provides a free web-based platform that allows open source software developers to store and manage their code and projects. Widely known in the software field, the site also serves as a hub where users and programmers can find open source software projects. Schweik & English (2012: 130–32) explain further how SourceForge serves as an important shared infrastructure for hundreds of thousands of open source projects. Schweik also noted that rules coded into the online systems used for collaboration often served a governance role.
- Meyer (Chapter 10), in his study of the development of the airplane, explained how a few central figures used the production of infrastructure in the form of bibliographies to turn a globally dispersed population of aviation enthusiasts into a knowledge-sharing community.
- Contreras (Chapter 4) noted the importance of various types of shared infrastructure in sustaining the genomic commons, including most importantly scientific journals and genomic databases. He also identified an important social dilemma in the provision of database infrastructure, given that work in producing and maintaining databases does not receive the traditional reputational rewards associated with scientific publication.

4. Informal governance institutions, and especially trusted leadership, often play key roles in knowledge commons governance

Informal governance, especially involving trusted leaders or decision makers, complemented and at times substituted for formal institutions in many of the cases studied here. Reliance on informal governance often seemed to grow out of relationships or norms predating the emergence of commons governance. In some cases, governance evolved toward greater formality over time. Future work should pay particular attention to the dynamic interactions between informal and formal governance institutions.

- Strandburg, Frischmann, and Cui (Chapter 5) showed that despite an array of formal governance mechanisms "on the books," the UCDC appeared to rely heavily in practice on informal governance and trusted leadership. This pattern may be a remnant of the informal collaboration among a small, close-knit community that preceded the UCDC and its formal governance regime. It also may be a function of the needs of the communities involved, including the need to accommodate different constituencies as well as the need to remain inclusive to facilitate growth. The

NIH grant process also vests ultimate responsibility for administering the consortium grant in a small group of consortium principal investigators, which may bolster the authority of those individuals, especially if they are widely respected and trusted.

- Contreras (Chapter 4) noted that in the case of the genome commons, "the formal rules established at the outset of the HGP were strongly influenced by the norms of the scientific community at the time." He traced the impact of those norms as the formal governance regimes evolved. Over time, as the communities have grown and as intellectual property rights and commercial motivations have taken on greater importance, various genomic commons projects have developed complex systems of formal rules dealing with issues such as the timing of data contribution, data use rights, and publication credit.
- Schweik (Chapter 7) also found significant reliance on informal governance (often, social norms) and trusted leaders for open source projects. He noted that significant effort on behalf of the project leader was among the most important determinants of a project's success and that most of the projects he studied (some of which were quite small) appeared to have a "benevolent dictator" model of leadership. Governance of these projects relied primarily on "very informal" social norms or on rules that were coded into the online collaborative systems used to coordinate work. Formal governance in the traditional sense was viewed negatively, though Schweik reported "some indications—as we expected—that institutions evolve and become more formalized as projects grow in numbers of developers."
- Madison (Chapter 6) described the almost-total reliance on informal governance norms within Galaxy Zoo, including substantial deference to strong informal and entrepreneurial leadership by the professional astronomers who launched the project and heavy reliance on informal social norms to moderate activity within the large community of volunteers. Even production of scholarly papers based on the Galaxy Zoo classification data was influenced heavily by a collaborative attribution norm that emerged informally within the project.

5. Commons governance often evolves over time, and commons seems to play an especially important role in the early stages of some industries

Several cases illustrated the proposition that commons governance may evolve as the number of participants grows or as innovation affects the nature of the shared knowledge or the balance between competition and cooperation within the group. For example:

- Schweik (Chapter 7) posed the following questions: "In moving toward a systematic study of these larger [open source] projects, key questions that we must ask are: [1] How do we systematically document the institutional designs of larger collaborations or collaborations between organizations? and, [2] How do we study the evolution of open source-like commons systematically?"

- Contreras (Chapter 4) framed the action arena for the genome commons study in terms of the *evolution of rules and norms*. He identified "a feedback loop [], in which policy-level decisions affect interactions within the action arena and cause participants to seek policy-level changes in subsequent iterations of policy making. These patterns emerge in the successive genomics projects that followed the HGP, whether publicly or privately funded."
- Murray (Chapter 11) described the evolution of mid-nineteenth-century journalism, based largely on informal commons governance through professional norms among newspaper editors, to mid-twentieth-century journalism based on more formal commons governance through a news agency, the Associated Press.
- Meyer (Chapter 10), in his study of the invention of the airplane, observed an evolution in three stages involving different social dilemmas: (1) an early period in which the creation of knowledge was motivated almost entirely intrinsically and the social dilemmas revolved around providing infrastructure for sharing that knowledge; (2) a period after successful invention in which commercial competition essentially destroyed the commons for knowledge about building airplanes, while a commons of flying practice remained intact in flying clubs; and (3) a wartime period during which sharing was effectuated through a government-facilitated industrial patent pool.
- Shah and Mody (Chapter 9) described the various paths along which user innovation may evolve into entrepreneurship, each involving different knowledge sharing structures.

6. Knowledge commons governance often does not depend on one strong type or source of individual motivation for cooperation

Knowledge commons entail cooperation in the building, sharing, and preservation of knowledge resources, but the reasons individuals cooperated in particular knowledge commons varied. Not only did different individuals cooperate for different reasons, but sometimes a single individual had multiple motivations for cooperating, partly intrinsic and partly social. Participants often had both competitive and cooperative motives and the balance between the two often varied between individuals or changed over time. Motivations often varied according to participants' roles as creators, maintainers, and/or users of shared knowledge resources. Yet the overall contrast to the traditional free rider story, in which individuals are assumed to compete for resources as a result of self-interest, is striking. This variety of motives is partially responsible for the variety of social dilemmas that arise in governing knowledge commons. For example:

- Intrinsic, noncompetitive motivations for creating and sharing knowledge were common. According to Strandburg, Frischmann, and Cui (Chapter 5), UCDC researchers were motivated by their commitment to patient care (most

were pediatricians) and their commitment to the close-knit researcher community. Contreras (Chapter 4) pointed out that genomic researchers were driven by their interest in the science. Fagundes (Chapter 13) grounded his case study of roller derby on this observation that derby participants are motivated by their love of the sport. Madison (Chapter 6) concluded that Galaxy Zoo volunteers were motivated by their desire to contribute to scientific progress and their interest in astronomy. Meyer (Chapter 10) showed that early aviation enthusiasts were motivated entirely by their fascination with the dream of flight.

- The opportunity and ability to use shared knowledge was frequently a motivation for those who created and contributed knowledge to a commons. Schweik (Chapter 7) noted that use was a major motivation for open source software programmers. Both Madison (Chapter 6) and Contreras (Chapter 4) showed that scientific researchers employ shared knowledge resources in their own research. Norms among nineteenth-century newspaper editors described by Murray (Chapter 11) permitted widespread copying of news, essentially creating a pool of information that each paper could use in producing its own local paper. Use was obviously an extremely important motivation in the wartime innovation commons described by Piper (Chapter 12).
- Shah and Mody (Chapter 9) suggested that the motives of user innovators may change over time. Where knowledge sharing may be motivated for an initial period by a desire to use pooled improvements and modifications, user innovators may turn to entrepreneurship (and may then limit knowledge sharing) when participation in the community becomes less satisfying for some reason, when there is an opportunity to turn a hobby into a career or when a market opens up outside of the dedicated user community.
- Intrinsic motivations to pool knowledge resources often coexisted with competitive motivations, raising challenges for commons governance. According to Strandburg, Frischmann, and Cui (Chapter 5) and Contreras (Chapter 4), rare disease and genomics researchers balance their intrinsic motivations to cooperate with their desire to succeed as academic researchers (measured in part by securing funding and publications). Madison (Chapter 6) detected a related balance among Galaxy Zoo researchers, who delayed publication of the Galaxy Zoo classification data until initial academic papers were published. Fagundes (Chapter 13) acknowledged that roller derby participants compete in the rink while cooperating in many other respects. Meyer (Chapter 10) noted that cooperation among aviation enthusiasts fell victim to commercial competition once a practical airplane was invented. Competition between newspapers grew heavier in the balance as communication became faster and circulation areas grew, yet Murray (Chapter 11) observed that sharing practices have reemerged in different form in the blogosphere.

II. Reflections on the Framework

The case studies in this volume were the first to employ the modified IAD framework described in Chapter 1. Experience with these case studies not only confirms the usefulness of the framework approach but also suggests additional nuances and ways to refine and improve it.

1. Applying the Framework to Some Institutions That Are Not Core Examples of "Knowledge Commons"

The case studies presented here support our intuition that researchers should cast a wide net in defining proper subjects for study. Because the framework is primarily methodological rather than normative, it proved useful in guiding study of a broad range of cases, some that were closer to what many researchers would identify as "core" or "typical" institutionalized knowledge sharing regimes (research consortia, OCCs) and others that may seem, at first glance, to be unusual subjects for a study of knowledge commons (Congress, roller derby). We continue to believe that a broad invitation is warranted. Collecting data about a wide range of what Fagundes called "commonsy" institutions will help in eventually determining the properties that distinguish knowledge commons from other governance regimes, and that distinguish successful, effective commons regimes from less effective or unsuccessful regimes.

2. Taking a Broad Approach to Identifying Relevant Resources and Participants

The framework helps researchers to avoid tunnel vision in identifying relevant resources and participants merely by prompting researchers to ask explicitly "What are the resources?" "Who are the participants?" Several case studies reported on a broader range of resources and participants than one might associate with a typical (or stereotypical) "knowledge commons":

- Strandburg, Frischmann, and Cui (Chapter 5) reported on over a dozen different types of resources shared within the UCDC community (and outside of the community) and recognized by the community members as relevant and important. They also reported on the importance of many different actors, ranging from principal investigators, researchers, and site coordinators to pediatricians, neuropsychologists, dieticians, and other healthcare professionals to NIH officials to pharmaceutical companies to patients, families, and the patient advocacy group.
- Contreras (Chapter 4) and Van Overwalle (Chapter 4B) discussed the many different types of data captured by the phrase "genomic data." Specifically, Van

Overwalle noted that "'genomic data' may refer to raw DNA sequence data (encompassing genomic sequences of individual humans, micro-organisms residing within the human body, and other organisms), to physiological data (e.g., data relating to the association between particular genetic markers and disease risk) and to phenotypic data (including elements such as de-identified subject age, ethnicity, weight, demographics, exposure, disease state, and behavioral factors)." Contreras reported that the "principal stakeholder communities" include funding agencies, data generators, data users, data intermediaries, data subjects and the public. Van Overwalle usefully differentiated among participants, "distinguish[ing] between the community per se which actually produces and shares the commons (including the data generators, data users, and data intermediaries) and the larger community, or social environment, in which the community per se is nested and which facilitates and empowers the construction of the commons. This social environment includes funding agencies and members of the public, especially as represented by patient advocacy and disease interest groups."

- Daniels's study of Congress as commons (Chapter 14) showed how legislators depend heavily on a legislative knowledge commons that involves staffers, technical experts, news media, other branches of government, and industry/lobbyists. Daniels emphasized the importance of identifying the rivalrous resources that were also relevant to the knowledge commons.
- Fagundes (Chapter 13) identified a variety of shared resources in roller derby, a counterintuitive example of knowledge commons. Shared resources include knowledge about the roller derby sport ranging from skating skills and rules to techniques for recruiting members and information about roller derby's countercultural social milieu. He also identified participant roles that would not spring immediately to mind, including trainers, referees, record keepers, and other volunteer non-skaters whose involvement brings them within the community.

3. Accounting More Explicitly for Evolution of Knowledge Commons Governance over Time

As discussed in Chapter 1 and illustrated in Figure 1.2, we expected knowledge commons to change over time as the exogenous variables (resources, communities, rule-in-use) evolve through the decisions and actions of actors in the various action arenas. We also noted the importance of narrative and history in determining knowledge commons governance, features that are inevitably dynamic, at least to a degree. We did not anticipate fully how dramatically the character and stability of some knowledge commons would be affected by changing interactions with the background environment or changes in the knowledge resources themselves. The important changes over time observed in some of the case studies in this volume raise a broader methodological issue that remains to be addressed: *how to study the evolution of knowledge commons.* Schweik (Chapter 7) posed the following

questions: "In moving toward a systematic study of these larger [open source] projects, key questions that we must ask are: [1] How do we systematically document the institutional designs of larger collaborations or collaborations between organizations? and, [2] How do we study the evolution of open source-like commons systematically?"

4. BEGINNING WITH GOALS AND OBJECTIVES AND IDENTIFYING ACTION ARENAS

Our initial discussion of the knowledge commons research framework did not fully anticipate the potential complexity in defining action arenas for knowledge commons. In the natural resource context, the primary operational action arena for a commons regime generally is the use of a specified natural resource by a community defined by geographic proximity. (Other action arenas operate at a rule-making or governance level.) Because knowledge resources are intangible and often are created by a self-selected group of commons participants, knowledge commons often form around particular goals and objectives rather than around preexisting resources tied to particular communities or particular geographies. When that is the case, there may be several primary action arenas at the operational level, and the most important action arenas may not be immediately evident at the outset of research.

To analyze a knowledge commons regime it may be most sound analytically to begin with goals and objectives, rather than resources, then to identify action arenas related to those goals and objectives, and then to identify resources, participants, rules, and so forth associated with each action arena. In practice, use of the framework is likely to be an iterative process, in which collecting data about particular knowledge resources may lead to the identification of additional goals and objectives, which may lead to the identification of additional participants or additional shared resources and so on. The UCDC case study (Chapter 5) proceeded in just this way, with study focused initially on the pooling of medical knowledge among researchers and later broadening to identify and study goals and objectives such as creating a pool of research subjects and patient data and associated action arenas such as the longitudinal study. The Galaxy Zoo case study (Chapter 6) likewise focused initially on the pooling of galaxy classifications and later broadened to examine related goals, including the production of publishable research and creation and maintenance of the volunteer forum and teaching resources for schoolteachers. The expanded scope of the inquiry and prioritizing goals and objectives helped to sharpen the contrast between Galaxy Zoo as knowledge commons and the nominally similar Nearby Supernova Factory, which was characterized instead as a kind of hierarchical firm.

The framework was critically important in ferreting out the various action arenas and resources involved in the UCDC study and in Galaxy Zoo. But we now believe that our initial conception of the framework did not put sufficient emphasis on the identification of action arenas using an iterative approach to goals and objectives, resources, and participants. This point is reflected, in part, in a question about the relationship between action arenas

and goals and objectives that we added to the description of the framework in the box, "Knowledge Commons Framework and Representative Research Questions," in Chapter 1.

5. IDENTIFYING SOCIAL DILEMMAS

As we have already discussed, knowledge commons governance presents a wide variety of social dilemmas in addition to the traditional free rider problem. To analyze an action arena and understand its rules-in-use, it is helpful to identify the social dilemmas faced by participants. We have added the identification of relevant dilemmas to the set of questions under "Goals and Objectives" in the framework as described in the box, "Knowledge Commons Framework and Representative Research Questions," in Chapter 1. To understand the social dilemmas faced by a group of commons participants, it is also useful to study their motivations, especially since a theme common to the case studies presented here is diversity of participant motivation.

6. IDENTIFYING SHARED INFRASTRUCTURE

Experience with the case studies in this volume suggests that shared infrastructure may be particularly important for constructing, maintaining, and governing knowledge commons. We suggest that future case studies focus specifically on identifying infrastructural resources created or used by the commons. In some cases, such as open source software, it will be important to include infrastructural constraints in the analysis of an action arena's "rules-in-use" in order to get a complete picture of commons governance. These points are reflected in questions about infrastructure added to the framework as described in the box, "Knowledge Commons Framework and Representative Research Questions," in Chapter 1.

7. IDENTIFYING BOTH NONRIVALROUS AND RIVALROUS RESOURCES

Although the study of knowledge commons focuses on the sharing of intangible, nonrivalrous resources, it is important to identify any rivalrous resources that are important to a particular action arena. As noted above, and emphasized by Daniels (Chapter 14), social dilemmas for knowledge commons governance can and do arise from competition or conflict over the allocation of nonrivalrous resources. We now emphasize the importance of identifying both rival and nonrival resources in the representative research questions in the box, "Knowledge Commons Framework and Representative Research Questions," in Chapter 1.

8. IDENTIFYING DILEMMAS AND ACTION ARENAS ASSOCIATED WITH BOUNDARY MANAGEMENT

As emphasized in Chapter 1, knowledge commons may have different types and degrees of "openness." In particular, because knowledge resources are nonrivalrous, knowledge

commons are likely to have to deal with multiple constituencies, including as users, creators, managers, or curators, and, in cases such as UCDC, subjects of the knowledge resources. These different constituencies may make different and sometimes conflicting demands on commons resources. It is important when identifying goals and objectives and action arenas to be aware of the possibility that important action arenas may be devoted to managing boundary conflicts among different participants. This point is now addressed by the questions about goals and objectives and governance in the box, "Knowledge Commons Framework and Representative Research Questions," in Chapter 1.

III. Looking Ahead

In her landmark book, *Governing the Commons,* Elinor Ostrom (1990) analyzed eighty-six case studies of natural resource commons from different sectors and geographic locations. She reported on decades of systematic scientific research that included empirical investigation and the development and testing of theories and models and identified eight design principles for stable commons management of natural resources. Ostrom inspired us, as she did thousands of others. Our book is intended as a tribute to hers. But ours is not the culmination of thirty years of research; rather it is a first step on what we hope will be a long, enlightening path.

We envision a three-part knowledge commons research agenda:

- Theoretical and empirical work using case study and other approaches focusing on various dimensions of knowledge commons and the social dilemmas confronting them (e.g., free-ridership, motivations and incentives, norms of behavior, and the design and evolution of governance).
- Building a library of knowledge commons case studies and corresponding structured database of case study information to enable identification and analysis of commonalities and differences among knowledge commons, to inform both theory and practice, and generally to support further qualitative and quantitative comparative research.
- Growing a collaborative research network of scholars from a variety of relevant disciplines to investigate the functionality and dynamics of knowledge commons and create infrastructure to facilitate its growth.[1]

The last part of the agenda is crucial. Serious progress on an empirically-based understanding of knowledge commons will require shared effort. We hope that others will

[1] An example of the type of long-term collaborative research network we envision is the International Forest Resources and Institutions network (http://www.ifriresearch.net/).

adopt and apply the modified IAD framework and help to refine it further. We are working to provide infrastructure for that effort, in the form of conferences, workshops, a website containing links to various useful resources, and, eventually a case study database. We also recognize, as did Ostrom herself, that there are no methodological panaceas and anticipate cooperating and collaborating with researchers taking other approaches to knowledge commons research. Accordingly, we end this book by extending an invitation to future collaborators and fellow travelers to get in touch with comments, questions, critiques, and results of your own research. Help us to create a knowledge commons for the study of knowledge commons!

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