Open Access and Information Commons[1]

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Open access commons are family of institutional arrangements that are far more pervasive in modern complex economies than is usually recognized in the economic literature. Core resources necessary for communications, innovation, trade, transportation, and energy are managed on the basis of symmetric use privileges open to all, deploying nondiscriminatory allocation based on queuing where congestion occurs, rather than on exclusive proprietary control used to achieve price clearance. Highways, roads and sidewalks, navigable waterways, and open squares are central to intercity and urban commerce. The public domain in knowledge, data, information, and culture forms the foundation of innovation, markets, and creativity. Open standards, the core Internet protocols, unlicensed wireless spectrum, and the privately-created open access commons in Free and Open Source Software (FOSS) runs most Internet infrastructure. More ambiguously, common carriage and public utilities that characterize basic infrastructures for energy and wired communications exhibit full or partial characteristics of open access commons.

The defining characteristic of open access commons, by comparison to property, whether individual or collective, is their utilization of (a) symmetric use privileges for (b) an open, undefined set of users in the general public, rather than (a') asymmetric exclusive control rights located in the hands of (b') an individual legal entity or defined group (club) use, and (c) their primary reliance on queuing and some form of governance-based allocation, rather than (c)' price-cleared models, for congestion-clearance and management. Far from being necessarily less efficient or unsustainable, for substantial classes of resources we have observed many critical resources migrating from provisioning based on a reasonably well-developed market in private exclusive rights to open access commons. These migrations have not occurred through regulatory intervention, but rather through private actions of users and producers. Carol Rose documented this transition in roads and squares in the nineteenth century;[2] and it was the case of open access Internet, which displaced proprietary services like Compuserve and Prodigy, in WiFi and similar open access wireless commons, which now carry the majority of wireless data communications despite early dominance of proprietary wireless carriage; it has been the case in software, where FOSS, in competition with proprietary substitutes, now accounts for much of the basic software for using the Internet; and it is

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[2] Carol Rose, The Comedy of the Commons: Custom, Commerce, and Inherently Public Property, 53 U Chi L Rev 711 (1986).

developing in diverse models of open access publication, both in "net native" sites like Wikipedia and many hundreds of thousands of lesser forums and in more traditional publication sectors, primarily in the scientific and educational fields.

Despite the ubiquity, apparently critical role, and competitive successes of open access commons in modern economies, little economic theory addresses itself to this surprising resilience and even emergence of open access commons in core parts of market-based societies. The baseline assumption is, instead, that open access commons are tragic:[3] rational actors pursuing their self-interest under an open access regime will suffer congestion and disinvestment. Public goods theory explains state or public ownership of some classes of resources—like lighthouses. These resources are still owned as property, usually by the government or a publicly-created body, and access to them may be open, where they are strictly non-rival, as with lighthouses or national security, or may be allocated by some other mechanism of public decision making, whether democratic or authoritarian, rational or corrupt. We have theories for group ownership of certain resources, initially club goods theory,[4] and more recently prominent, the Ostrom school of commons theory.[5] Both these theoretical approaches, however, require exclusion of non-members or non-commoners from the resource set owned as a club or a common property regime. A defining feature of both theories is that, by their own terms, they would converge with standard economic theory in predicting that, for example, open access spectrum would fail, and certainly under-perform a market in spectrum clearance rights. And yet, over the past fifteen years, WiFi and similar open spectrum approaches have outpaced property-like wireless carriage and now carry the majority of data communications. They would similarly predict that a protocol capable of auctioning or otherwise prioritizing clearance slots for congestible data carriage networks, like IBM's Token Ring for local area networks, or some network protocols that competed with the Internet protocol, would be more efficient and outperform protocols based on a simple first-come, first-served protocol with no limitations on who can use the system, like Ethernet or the Internet Protocol, TCP/IP. And yet the history of network technology in the past thirty years has seen protocols based on an open access commons model of management—Ethernet and TCP/IP—

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3 Garrett Hardin, The Tragedy of the Commons, 162 Science 1243, 1244–45 (1968).

4 See James Buchanan, An economic theory of clubs 32 *Economica* 1-14 (1965); Mancur Olson, The Theory of Collective Action (1965); Eitan Berglas, On the theory of clubs, 66 Am. Econ. Rev., 116-121 (1976). See generally R. Cornes & T. Sandler, The Theory of Externalities, Public Goods, and Club Goods (2d ed. 1996).

5 Elinor Ostrom, Governing the Commons: The Evolution of Institutions for Collective Action

outcompete protocols able to achieve price clearance, and gain dominance as the core standards of network communications.

Part 1 of this chapter offers a brief overview of the commons literature. Part 2 offers thumbnail case studies of the emergence of open access commons in the digitally networked environment. The emergence of unlicensed wireless in physical infrastructure space; the rise of TCP/IP and Ethernet in networking protocol space; the emergence of Free and Open Source Software; the emergence of commons-based production of content on the Net and of open access publishing in scientific and educational materials. Part 3 suggests that the emergence of open access commons reflects the combined effect of (1) innovation economics under conditions of high uncertainty; (2) diversity of human motivations (generally studied in economics as a branch of behavioral economics); and (3) political economy, or an effort to find a new basis for social embedment of markets. It concludes with a brief typology of open access commons and their proprietary parallels, organized along the dimensions of the models of provisioning the resource and models of governing the resource, once provisioned.

1. Two tales of the commons: An intellectual history

Garrett Hardin's parable of the *Tragedy of the Commons* set the terms of the debate over the commons for the following two generations. Following closely on the heels of Mancur Olson's *Logic of Collective Action*, it laid the intellectual foundations for an abiding skepticism about the feasibility of open access commons. Resources to which anyone had a right of access would be overused and underinvested. Every extracted unit provided its full benefits to the extractor, while sharing its disinvestment costs with all other potential and future extractors; by contrast, every invested unit imposed its full costs on the investor, but the benefits it produced were shared with all other and future extractors. To avoid overextraction and underinvestment under these conditions, the resource had to be owned and managed—either regulated by the state or by private owners. Demsetz's theory of property rights followed these basic insights, arguing that property rights would be introduced as soon as the marginal increase in the value of the resource gained by converting it from commons to property became larger than the transactions costs of creating and maintaining a property regime in the commons.

a. The Ostrom School

Two schools of work on the commons developed in response to this baseline story. The first, anchored in the work of Elinor and Vincent Ostrom at the Workshop in Political Theory and Policy Analysis at Indiana University was primarily a response to Olson. Over decades of painstaking field research, the Ostrom School showed that groups can solve the problems of collective action without relying on the state for either of the two then-dominant models: directly regulating behavior or defining and enforcing private property rights. The work emphasized detailed studies of a carefully delineated set of institutions—limited common property regimes (CPRs)—applicable to a carefully defined class of physical resources: common-pool resources.[6] Using highly context-specific, detail-rich case studies of these settings, under the Institutional Analysis and Development (IAD) framework Ostrom developed,[7] and abstracting from them to the mainstream game theory and public choice theory, Ostrom was able to carve out a distinct and robust field that had enormous real-world implications for development policy and played a critical role as a major intellectual critique of the dominant model that privileged property rights as the core solution to collective action problems.[8] CPRs range from the lobster gangs of Maine,[9] through Spanish irrigation districts,[10] to Japanese fisheries.[11]

CPRs are not open access commons. Indeed, Ostrom insisted on "the difference between property regimes that are *open-access*, where no one has the legal right to exclude anyone from using a resource, and *common property*, where members of a clearly defined group have a bundle of legal rights including the right to exclude nonmembers from using that resource."[12] This definition would exclude congestible open commons like roads and highways, WiFi or the Internet. The Ostrom school focused not on open access, but on the fact that groups could solve their collective actions problems without the state or exclusive property as among the members of the group. Nowhere is this clearer than in Ostrom's description of the irrigation districts in Alicante, that used a CPR-specific system of tradeable, divisible scrip-denoted rights in fractions of minutes of water. Such a fluid market was "a commons" in Ostrom's framework, because it derived from a collectively created, non-state, non-state-defined-property system. The critical policy claim of the Ostrom School was that these systems embodied local knowledge, and were superior both to state regulation and standardized property rights

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6 Ostrom, *supra*.

7 See Elinor Ostrom, *Background on the Institutional Analysis and Development Framework*, 39 Pol Stud J 7, 9–11 (2011).

8 Ostrom, Governing the Commons, *supra*.

9 See Edella Schlager and Elinor Ostrom, *Property-Rights Regimes and Natural Resources: A Conceptual Analysis*, 68 Land Econ 249, 257–59 (1992).

10 See Ostrom, *Governing the Commons* at 69–82 (cited in note 13).

11 See Arif Satria, Yoshiaki Matsuda, and Masaaki Sano, *Contractual Solution to the Tragedy of Property Right in Coastal Fisheries*, 30 Marine Pol 226, 233–34 (2006).

12 Ostrom, Governing the Commons, at 121.

systems, in that both of the latter abstracted too greatly from the diverse and distinct features of the resource set governed by the CPR. The primary policy implication was that rationalized modernization programs, whether implemented as regulatory interventions or state-sponsored public works, or as "privatization" through parcelizing the CPR into individualized property rights, were likely to cause greater disruption and loss of local knowledge about proper management of the common pool resource than leaving the existing CPR in place.[13]

b. Open Commons

The majority of the work on open commons in the past quarter century has revolved around information and the Internet. But the first work to challenge the idea that open access commons were systematically tragic Carol Rose, *The Comedy of the Commons*.[14] Rose examined common law doctrines under which private property came to be declared open to the public as a whole: where the set of individuals who have the right is open and undefined. She discussed, in particular, roads and navigable waterways, as well as open squares or fields where gatherings (both social and market) were traditional. Rose's primary explanation was an early version of network economics—demand-side increasing returns to scale made it so that opening these resources to public use substantially increased usage, which, in turn, produced substantial enough positive externalities to dominate congestion costs caused by making the road or navigable waterway an open access commons.

Most of the work on open commons has occurred in the relatively "easy" case of noncongestible information goods and the public domain, as well as in the "harder" case of congestible network goods: Internet and wireless communications. Information is nonrival and partially non-excludable, which means that to the extent that proprietary mechanisms succeed in reducing the nonexcludability, they systematically lead to underutilization of information relative to optimal (the nonrivalry means the marginal cost of information, once produced, is zero, and any positive price leads to some deadweight loss),[15] and because existing information

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13 See Hess and Ostrom, 66 L & Contemp Probs at 123 (cited in note 3).

14 Rose, *The Comedy of the Commons: Custom, Commerce, and Inherently Public Property*, 53 U Chi L Rev 711, 778–80 (1986).

15 This has been a standard argument since Richard R. Nelson, *The Simple Economics of Basic Scientific Research*, 67 J Polit Econ 297, 302 (1959). For another discussion of the perverse effect on incentives of open rights to information, see Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity: Economic and Social Factors* 609, 616–17 (Princeton 1962).

is a core input into the production of new information (e.g., established scientific facts as a basis for new investigation; past innovations to new ones; news reports input into analyses etc.), treating information as property also increases the cost of new information production.[16] So much is well established and thoroughly modeled, and it is commonplace that intellectual property sets up a tradeoff between the incentives it creates for innovators and creators through enabling them to extract rents from the products of their investment, and the underutilization of the information by users and second-generation information goods producers that result from the non-rival nature of information.[17]

In the early 1990s Litman published an early analysis of how copyright systematically preserved a substantial public domain, by design, as a fundamental resource set for works subject to copyright,[18] and Pamela Samuelson investigated the critical role of open access to the incremental development process at the heart of software development.[19] Boyle then began to expand this view and locate it in a political economy, framing the tension over property in information, knowledge, and cultural as one between producers who depended on access to existing information, such as software developers, journalists, or rap artists, and producers who depended on control over stocks of cultural goods.[20] Lemley criticized efforts to strengthen intellectual property rights based on endemic market failures in information production, as well as the "on the shoulders of giants" effect and the significance of positive externalities in innovation,[21] and Cohen underscored the unique economics of information to

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16 Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J Econ Persp 29, 29 (Winter 1991).

17 See James Boyle, *The Public Domain: Enclosing the Commons of the Mind* 17–41 (Yale 2008); Josh Lerner, *150 Years of Patent Protection*, 92 Am Econ Rev 221, 222 (2002).

18 Jessica Litman, *The Public Domain*, 39 Emory L J 965 (1990)

19 Pamela Samuelson, Benson *Revisited: The Case against Patent Protection for Algorithms and Other Computer Program-Related Inventions*, 39 Emory L J 1025 (1990); Pamela Samuelson, *Should Program Algorithms Be Patented?*, 33 Comm ACM 23 (1990). Her work clearly influenced the thinking of leaders in the software developer community, see Simson L. Garfinkel, Richard M. Stallman, and Mitchell Kapor, *Why Patents Are Bad for Software,* 8 Issues in Sci & Tech 50, 53 (1991).

20 James Boyle, *Shamans, Software, and Spleens: Law and the Construction of the Information Society* 174–84 (Harvard 1996)

21 Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 Tex L Rev 989, 1049–57 (1997).

negate the growing use of the analogy of physical property to support stronger intellectual property rights.[22]

My own worked built on these insights and extended them in two ways. First, by analyzing open spectrum commons, I expanded the analysis from the domain of strictly non-rival public goods (information, knowledge, and culture) to rival or congestible goods where open innovation effects dominated congestion-clearance efficiency effects.[23] Second, I explained the shared institutional form of the public domain and other open commons in terms of a shift in the institutional foundation of the industrial organization: decentralization of innovation.[24] A shift from asymmetric exclusive rights to symmetric use privileges underwrote a decentralization of innovation, creativity, production and exchange, and thereby permitted greater experimentation and diversity.[25] Lessig combined these insights into an argument for preserving commons at every layer of the Internet: at the level of physical and logical infrastructures, and the level of the creative content people exchange over it.[26]

Frischmann then tied the work on Internet, wireless, and information to the work Rose did by developing a more general theory of commons in infrastructure.[27] He developed an

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22 Julie E. Cohen, Lochner *in Cyberspace: The New Economic Orthodoxy of "Rights Management"*, 97 Mich L Rev 462, 466 (1998).

23 Yochai Benkler, *Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment*, 11 Harv J L & Tech 287, 359 (1998); Yochai Benkler, *Some Economics of Wireless Communications,* 16 Harvard Journal of Law & Technology 25 (Fall 2002).

24 Yochai Benkler, *The Commons as a Neglected Factor of Information Policy* *2 (speech presented at the 26th Annual Telecommunications Research Conference Oct 5, 1998), online at http://www.benkler.org/commons.pdf (visited Mar 22, 2013); Yochai Benkler, *Intellectual Property and the Organization of Information Production* *42–44 (unpublished manuscript, Oct 1999), online at http://www.benkler.org/Ipec99.pdf (visited Mar 22, 2013); Yochai Benkler, *Free as the Air to Common Use: First Amendment Constraints on Enclosure of the Public Domain*, 74 NYU L Rev 354, 424 (1999).

25 Yochai Benkler, *The Battle over the Institutional Ecosystem in the Digital Environment*, 44 Comm ACM 84, 88 (2001).

26 Lawrence Lessig, *The Future of Ideas: The Fate of the Commons in a Connected World* 147–233 (Random House 2001).See also Yochai Benkler, *From Consumers to Users: Shifting the Deeper Structures of Regulation Towards Sustainable Commons and User Access*, 52 Fed. Comm. L.J. 561 (2000).

27 Brett M. Frischmann, *An Economic Theory of Infrastructure and Commons Management*, 89 Minn L Rev 917 (2005).

approach based on demand side failures. Defining “infrastructure” as a broad range of goods that are important in the downstream creation of other goods, particularly in a broad range of public goods and “social goods” like rule of law or basic capabilities that a society’s moral commitments require that everyone have, and which “may be consumed non-rivalrously for some appreciable range of demand,” Frischmann argued that failures in demand to express the full social value of these infrastructure goods will be systematic, and will systematically lead to underprovisioning of the infrastructure good if left as a private property model.[28]

2. *Open access emerging in the presence of proprietary alternatives: cases from the networked environment*

Over the past twenty five years, open access models have repeatedly emerged and became stable, sometimes dominant, models for provisioning and managing critical segments of all layers of the information environment. The repeated success of these practices suggests that, at a minimum, open access commons are more stable and sustainable than the standard tragedy of the commons model would propose. The fact that they were chosen freely, rather than imposed through a regulatory process, and succeeded in terms of market adoption by consumers or firms in the presence of well-developed proprietary alternatives, suggests further that they provide some affirmative advantages over proprietary or closed-commons alternatives with which they compete.

1. *Unlicensed Spectrum*. No core resource in contemporary society better reflects the intellectual and institutional history of thinking about rationalized regulation of public goods, the shift to privatization and price-cleared markets, and finally the emergence of commons, than spectrum regulation.[29] Ubiquitous connected computing would simply be impossible without extensive use of wireless communications. From the now-mundane smartphone to the exotic driverless car, through heart monitors, smart grids, or inventory management and shipping, the major innovations in early twenty first century information technology, built on tiny computers embedded in everything, could not develop if they were limited to communicating through wires. From the early 1910s until the 1990s, “spectrum,” the range of frequencies usable for wireless radio communications, was treated as a regulated public good subject to administrative rationing and regulation. It was the subject of public ownership and funding in most of the world, and the subject of licensing and close federal regulation in the public interest in the United States. For half that period, spectrum regulation was also the

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[28] Brett. M. Frischmann, Infrastructure: The Social Value of Shared Resources (Oxford 2012).

[29] For a more complete intellectual history with citations see Yochai Benkler, Open Wireless vs. Licensed Spectrum, Evidence from Market Adoption, 26(1) Harv. J. Law & Tech. 69, 76-100 (2012).

subject of a sustained intellectual effort to explain that clear definition of exclusive property rights, initial allocation through auction, and subsequent allocation through flexible secondary markets would be a far superior alternative to the command and control regulation that was the exclusive model used throughout the world to regulate spectrum. By the early 1990s, the superiority of a property-in-spectrum market had become the orthodoxy among economists working on wireless regulation, and the private property approach gained partial acceptance in institutional practice. Over the course of the 1990s spectrum auctions became the norm, and by the early 2000s, secondary markets, particularly in the United States and Australia, were made substantially more flexible.

By the late 1990s, however, a technological alternative had developed that utilized "junk bands" that had been set aside as open access commons for the emissions of industrial, scientific, and medical radio signals. In 1998 the precursor to the WiFi standard was adopted, and in 1999 the first WiFi standard 802.11b was adopted. Initially treated as a regulatory backwater, and intellectually rejected by the mainstream of economic thinking on the subject, unlicensed wireless spectrum drew innovation from a wider range of companies and amateurs than those involved in proprietary spectrum. Investing in computation-intensive cooperative architectures to manage congestion, rather than on clearing competing bids for exclusive pricing, the wireless capacity of unlicensed spectrum began to roughly double every 20 months, roughly parallel to Moore's Law for computation capacity. By 2012, entire industries that had been projected as major areas of growth for proprietary wireless carriers—mobile health applications, smart grid communications, mobile payments and inventory management—had come to be dominated by a range of unlicensed wireless technologies, leaving proprietary spectrum-based applications niche markets. Even the most obvious success of cellular proprietary architecture, mobile internet access data, had come to mix WiFi and cellular, and over time the majority of data, even to smartphones, came to be carried over WiFi.[30]

WiFi and similar bands that have become the predominate infrastructure for wireless data communications are open access commons with precisely the characteristics that the tragedy of the commons predicted would lead to tragedy, under conditions that attracted substantial orthodox scholarship that predicted precisely this failure, but reality has in fact gravitated in favor of a true open access commons. This outcome was the product of two competing dynamics. One dynamic was that at the margin, an owner of any given slice of spectrum could clear competing uses and deliver more reliable communications capacity in that band. The other dynamic was that an open access band permitted any device, manufactured by any manufacturer and deployed by any consumer for any purpose, to be deployed, tried,

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[30] See Benkler, *Evidence from Market adoption*, for detailed analysis of these sectors.

and adopted or abandoned based on its effectiveness for the task required. In the open access bands no entity has exclusive control to regulate who deploys what device where. That openness created a sufficient level of innovation by diverse producers, innovation in using computation or coordination to solve "noise" and innovation in services and architectures, that it has resulted in greater carrying capacity for the commons than is available in proprietary bands. As a practical matter, the open, decentralized innovation permitted in open access spectrum dominated whatever higher efficiency was obtainable from centralizing decisions about allocation and assignment in proprietary bands in most classes of communication. Proprietary bands retain their advantage in certain important types of communications, particularly communications that move very fast and need continuous coverage, but have been overtaken by commons-based models in most sectors that require wireless data communications capacity.

2. *TCP/IP vs. ATM*. In 1985 TCP/IP was adopted by the Internet Advisory Board (an informal collection of engineers working on the Internet problem) as the Internet protocol. TCP/IP is an open access commons, in the sense that it treats all packets identically, and requires the developers of end applications to design their applications so they are robust to any likely delay that results from queuing being the congestion management protocol. It developed and was adopted as an informal protocol, by volunteers who claimed no proprietary interest in it, even though there were both proprietary firm-developed alternatives from IBM and DEC, and formal standard body alternatives, the International Organization for Standardization (ISO) and the International Telecommunications Union (ITU). Most pertinent from our perspective here was the effort, primarily in the 1990s, to develop a protocol that would allow telecommunications carriers to differentiate between packets and provide priority to some packets, which, in turn, would permit price clearance over queuing. The Asynchronous Transmission Protocol (ATM) was touted by telephone companies as the next generation of Internet protocol, but in fact failed to outcompete its open access competitor. The rate of innovation enabled by the fully open standard, with its commitment to end-to-end open innovation, outcompeted those applications developed to take advantage of a more controlled set of network resources.[31]

3. *Free and Open Source Software (FOSS)*. Moving from physical infrastructure and standards to software, the well-known story of FOSS has served as a poster child for the success

[31] Barbara van Schewick, Internet Architecture and Innovation (MIT Press 2010).

of commons-based strategies for over a decade.[32] FOSS reflects a licensing practice that voluntarily "contracts out" of a proprietary regime and instead adopts an open access commons. All FOSS licenses create an open access regime for the software developed. Anyone can copy the code, modify it, use it, and redistribute modifications if they so choose. The major division among the various licenses is that some licenses, most prominently the BSD licenses, create a simple open access regime. The other class, most prominently the GPL, imposes a reciprocity condition on the rights of any user who *modifies and distributes* the software. That is, any modified software under the GPL must be released under the same open access terms that the modifier received it. But even the GPL is open access (a) with regard to use, redistribution, and modification for own use; and (b) imposes a nondiscriminatory reciprocity requirement on all, essentially a requirement to reseed the commons as a condition for making certain, more intensive uses of it.

By the end of the first decade of the twenty first century, FOSS had come to account for between 65% and 70% of the web server software market; about 80% of server-side scripting languages; an undocumented but large portion of embedded computing running Linux, as well as forming the kernel of the handheld Android operating system; and accounting for about one third of the web browser market, in the form of Firefox. By one account, about 40% of firms engaged in software development engaged at least in some of their work in FOSS development.[33] FOSS has certainly not driven proprietary software development out of the market, but considering that it is based on a development model in which no one exerts exclusive rights over the final project, and about half the people involved in any significant extent are not paid for their contributions, the growth, success, and sheer technical excellence of FOSS defies explanation under traditional models that privilege proprietary and firm-based development. There are aspects of FOSS that go directly to organization theory, but are beyond the scope of this chapter.[34] For our purposes here, it is enough to note that one of the most dynamic, growing areas of innovation and production has seen a widescale, sustained, and effective adoption of an open access commons in its core resources, both inputs and outputs, even on the background of a well-developed property system and a well-developed set of firms

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[32] Glenn Moody, Rebel Code: Linux and the Open Source Revolution (Basic Books 2002); Christopher Kelty, Two Bits: The Cultural Significance of Free Software (Duke University Press 2008); Carles M. Schweick and Robert C. English, Interet Success: A Study of Open-Source Software Commons (MIT Press 2012).

[33] Josh Lerner & Mark Schankerman, The Comingled Code: Open Source and Economic Development (MIT Press 2010).

[34] For a review chapter see Yochai Benkler, Peer Production and Cooperation, forthcoming in J. M. Bauer & M. Latzer (eds.), *Handbook on the Economics of the Internet,* Cheltenham and Northampton, Edward Elgar

that were developing software on a proprietary model before FOSS burst on the scene as a major organizational and institutional alternative.

4. Wikipedia and commons-based peer production of content more generally. Paralleling FOSS, Wikipedia is one of the handful of most visited sites on the Internet and has established itself as one of the most important general knowledge utilities on the Web. It is edited by thousands of volunteers who manage their affairs internally without contracts, property, or state fiat, and without payment. Its inputs and outputs are all open access commons, licensed under a Creative Commons Attribution ShareAlike license, which shares its core features with the GPL described above, applied to cultural creations as opposed to software. Comparative studies over the years have mostly found Wikipedia to be of reasonable quality: imperfect, but not more so than other encyclopedias, including the standard-setter, Britannica. Studies oriented in particular toward scientific entries found Wikipedia to be reliable. The National Cancer Institute study in 2010 was a particularly powerful example, where Wikipedia articles on various common cancers were found to be of equivalent accuracy, though less user-friendly and readable, than the NCI's professionally produced explanations for patients.[35]

In terms of formal institutional framework, Wikipedia is an open access commons. Moreover, organizationally and technically, it is designed to permit anyone to edit it, whether they log in as a user or not, although no one is paid to do so. Lacking contract, exclusive property, or fiat, Wikipedia is the most complex and successful instance of large-scale sustained self-governance that we have observed on the Net, and quite possibly anywhere. For close to a decade, as of this writing, the number of editors who contributed more than 5 edits per month to Wikipedia in all languages has floated between 75 and 85 thousand, and the number of editors who contributed more than 100 edits per month has floated between 10.5 and 11.5 thousand; the English-language Wikipedia has about one-third to 40% of those numbers, respectively. By any account, that is a very large number of active contributors who are managed in a complex, vague system of overlapping elements, none of which quite fit any crisp, well-defined model of governance. As Wales put it, "Wikipedia is not an anarchy, though it has anarchistic features. Wikipedia is not a democracy, though it has democratic features. Wikipedia is not an aristocracy, though it has aristocratic features. Wikipedia is not a monarchy, though it has monarchical features."[36] A particularly insightful analysis of this set of overlapping

35 Rajagopalan *et al* (2010). "Accuracy of cancer information on the Internet: A comparison of a Wiki with a professionally maintained database". Journal of Clinical Oncology 28:7s, 2010.

36 Jimmy Wales, "From Jimbo Wales' user talk page," quoted in Wikimedia, "Meta:Talk:Benevolent Dictator," Wikimedia, March 16, 2007, http://meta.wikimedia.org/?oldid=544462

features is developed in three chapters of Joseph Reagle, *Good Faith Collaboration*,[37] although the work on Wikipedia governance is extensive, and a substantial portion of it is more critical of one or many aspects of the community's governance processes and practices.[38]

While Wikipedia's position as the leading instance of commons-based peer production is clear, smaller-scale projects that rely on open access commons for cultural production are legion. Wikia, the company founded by Jimmy Wales to host wikis, hosts over 10,000 Wikis; the P2PValue project, funded by the EU, is building a large database of hundreds of case studies of peer production projects.[39] Rather than an exception or a quirk, building knowledge bases using commons-based, rather than proprietary models has become a standard approach in the menu of possible models.

Wikipedia and FOSS are the most visible and successful examples of an alternative production model that has developed online: commons-based peer production.[40] The focus of this chapter is on commons, and largely excludes discussion of the economics of distributed innovation or peer production specifically. Briefly, the simplest model of peer production focuses on transactions costs. Social exchange is a transactional framework parallel to price-cleared, managerial, and government transactional frameworks. The Coasean transactions costs explanation of the firm can then be extended to social transactional frameworks. In particular, where human capabilities and motivations are diverse and therefore hard to specify and contract, where tasks are complex and require diverse forms of human capital and insight, and where resources that could go into an information production task are similarly diverse and may be possessed by different people, the transactions costs associated with a proprietary information production project—including contracting both for the necessary information inputs and the necessary human resources, can be very high. Social production allows people to self-assign, explore a large opportunity space of information resources in the commons and potential collaborators, and get together without the associated contracting costs, and without

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37 Joseph Michael Reagle Jr., Good Faith Collaboration: The Culture of Wikipedia MIT Press 2010 chapters 4-6.

38 An excellent bibliography is found in Mayo Fuster Morell, The Wikimedia Foundation and the Governance of Wikipedia's Infrastructure, Historical Trajectories and It's Hybrid Culture, in Critical Point of View, eds. Geert Lovnik and Nathaniel Tkacz (Institute of Networked Cultures, Amsterdam 2011); the volume generally collects a substantial amount of recent work that develops a critique of the more optimistic interpretations of Wikipedia.

[39] See http://directory.p2pvalue.eu/home.

[40] See Yochai Benkler, Coase's Penguin,or Linux and the Nature of the Firm, 112 Yale Law Journal 369 (2002).

the monitoring and compensation system costs associated with firm-based, proprietary production. Where information inputs that are nonrival can be combined with practices that require little capital or capital already in service in households (e.g., computers & communications capacity), and human time that would otherwise be focused on consumption can be refocused on production that treats the tasks as play, social production can emerge as the most efficient model.[41] Similarly, collaborative user innovation is particularly effective where communication costs are low and the design task can be rendered modular but would be very expensive were it borne by a central actor.[42]

5. Open Access Publication and Creative Commons. Beyond peer production we are observing substantial efforts to shift practices that have in the past emphasized proprietary control to commons-based models. Academic publication in particular has seen a significant shift toward open access publication.[43] In some disciplines, most prominently physics and computer science, academic publication is almost exclusively open access. That is, the research outputs published are available under an open access license. In other disciplines with more established dominant publishers, most importantly biology and medicine where the dominance of proprietary publications like Science and Nature is difficult to surmount because of the importance of publication in those venues for authors' professional advancement, open access publishing has developed more slowly. Nonetheless, even in these areas, the emergence of the PLoS (Public Library of Science) journals has create a significant venue for high quality scientific papers even in the presence of these extremely high impact proprietary journals. At the time of this writing, PLoSOne has become the largest scientific publisher in the world.

Open access scholarly communication has its roots in several efforts beginning in a 2000 petition called for by Harold Varmus, Patrick O. Brown, and Michael Eisen, calling on senior scientists to commit to publish only in open access journals. In late 2001 early 2002, many of the aspirations of the movement were set in the Budapest Open Access Initiative. The core idea was that scientific publication has never been driven by royalty payments to authors or reviewers, and while the cost of professional production could be significant in some journals, the pricing of journals by publishers reflected monopoly power over access to knowledge that was generated by scientists funded through public and philanthropic funding, who had interest

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[41] Benkler, Coase's Penguin.

[42]Baldwin, C. and von Hippel, E., 2010. Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation , MIT Sloan School of Management Working Paper # 4764-09 Harvard Business School Finance Working Paper No. 10-038 SSRN download url:
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1502864.

[43] For an extensive review of the history, types, and progression of open access see Peter Suber, Open Access (MIT Press 2012).

in the widest possible dissemination of their work, rather than high royalties, which they themselves did not enjoy. Over the fifteen years of its development, Open Access publication has increased, several major universities have undertaken to have at least the pre-publication version of their faculty's work available in open access repositories, and several major government and philanthropic funding agencies have mandated or at least support open access publication fees, which go to publishers in lieu of royalties to fund the professional editing aspect of the work while keeping the works available for downloading by anyone, anywhere, free of charge. Of all other forms of successful open access practices, Open Access publishing of academic work is the least puzzling. Basic science is a public good that enjoys public and philanthropic funding, and so separates the production price and the consumption price in a way that overcomes some of the standard problems with private provisioning of public goods using proprietary exclusion. Academic scientists likely self-select because of a preference profile that is happy to trade off money income for a range of non-monetized desiderata, from status to freedom to be creative. Nonetheless, it offers a valuable example of a practice that is a critical element of growth in market societies that has moved away from an exclusively proprietary model toward an open access model over the past fifteen years.

6. Open Access case studies: conclusion. In all, the diverse case studies, from spectrum and standards, to software, general knowledge, cultural production, and academic publication are intended to underscore the extent to which in the digitally networked information environment we have seen, repeatedly and significantly, the voluntary adoption of open access commons-based practices in the presence of pre-existing proprietary models. This has happened not as holdovers from pre-industrialization cultural practices in the global market periphery, but at the heart of the most advanced economic sectors in the most advanced economies.

3. Theories of commons

Open access commons are a family of institutional solutions that respond to three practical problems under certain resource conditions. The three practical problems are (a) high persistent positive externalities, of which nonrivalry in information goods is an extreme case; (b) uncertainty, under which exploration trumps appropriation and has its primary impact in innovation; and (c) social disembeddedness, or the risk that markets will drive resource utilization in ways that will lead to social instability or political intervention.

In terms of characteristics of the resource set, open access is most feasible in the case of resources that are either nonrival (information; knowledge; standards) or partially congestible, with variable loads over time such that for substantial ranges of their operation their use is not congested—roads, electricity, and spectrum have this characteristic. The extent to which the resource is depleted by use or perfectly renewable also contributes to its amenability to open access management. The less congestible the resource is the less benefit is gained from introducing asymmetric excludability except as a solution to initial provisioning. The more prominent the periods of noncongestion in the total utilization range, the less benefit there is for instituting an asymmetric exclusivity regime to clear the peak demand periods. The more a partially-congestible resource is renewable, like spectrum, the less significant the problem of disinvestment, or cumulative congestion over time, is. The more the resource requires continuous reinvestment, such as with roads or the electricity grid, the more we see members of the open access family that are integrated with public provisioning or some other form of payment for use that nonetheless retains the symmetric use privileges but attaches it to use payments. Open access can be required in a society even where all these conditions are absent, where the social implications of exclusion dominate the efficiency concerns of nonexclusion. Emergency room care is an obvious example. As Kapczynski and Syed have shown, there are classes of rules of intellectual property that best explained by this form of deep nonexcludability.[44]

Positive externalities

Beginning with Rose's *Comedy of the Commons*, which explored the emergence of open access commons in roads and navigable waterways as a function of the positive returns to scale that travel provided a growing continental commercial system,[45] a core explanation of the emergence and success of open access commons has been their utility in providing the resources necessary to support high positive externality activities. Frischmann then emphasized these "spillovers" as central to a wider range of "infrastructure" goods.[46] Information goods are a particular subset of this problem, in that (a) the nonrivalry means that efforts to internalize the positive externalities by creating enough exclusivity to support appropriation through charging a price will necessarily result in deadweight loss;[47] (b) high exclusion leads to higher costs for downstream innovators or creators, because of the "shoulders of giants" effect. As a result, the property-like solutions represented by patents and copyrights suffer from the well-known limitations and imperfections, while the public domain plays a critical role in seeding new innovation and creative expression.

Open access to academic publication is an example. The understanding of the role academic science plays in early-stage research and investigation as producing high positive spillovers that cannot be captured through intellectual property is longstanding. The basic idea is that investigation that tries to internalize all its social value will necessarily focus on appropriable innovation, and will therefore necessarily be more narrowly focused. Given that

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[44] Amy Kapzcynski and Talha Syed, *The Continuum of Excludability and the Limits of Patents*, 122 Yale Law Journal 1900 (2013).
[45] Rose at 768.
[46] Frischmann, supra, 2005, 2012.
[47] For the original statement of the tradeoff, see Arrow 1962, *supra*; for an overview of the problem, see Oren Bracha and Talha Syed, Beyond the Incentive-Access Paradigm: Product Differentiation and Copyright Revisited, 92 Texas L. Rev. 1841 (2014).

innovation is critical to later innovation, that it is a cumulative process, and that it is critical to growth, a proper growth-oriented policy will seek to assure that there is some level of public funding for “basic” research—that is, research usable as input in a wide range of research projects. Open access to that basic science as input for follow-on innovation and investigation maximizes its spillovers. Debates over patenting of university innovation occur precisely along the lines of whether some degree of exclusivity will lead to greater effort to convert the basic science into usable technology, as compared to the risk that this exclusivity will lead to a narrowing of focus and a gain, in terms of appropriable investment, that is outweighed by the loss in focus on basic, high-positive-spillover science.[48] The open access publication movement of the past fifteen years takes this basic logic and applies it to the area where the argument in favor of appropriation is even weaker than the patent, because the investment necessary to convert a finished research product into a published paper is much smaller than the investment necessary to bring a science innovation to a product market, and the majority of the labor is done in peer review, as professional activity attendant to publication. Similarly, because science is highly incremental, the on the shoulders of giants effects is pronounced, further supporting the open access models. This also explains in large measure why software, where innovation is widely seen as highly incremental, is a field where we see open access commons in the form of FOSS licensing being chosen by both market and nonmarket actors.

Roads, in the nineteenth and twentieth centuries, and the Internet and spectrum, in the twenty-first, are examples of congestible goods associated with very high positive externalities. The more people use roads to travel to a city or between homes and workplaces; or use the Internet or spectrum to connect to services and social practices, the more congested the shared resource becomes, but also the more valuable the dependent activities. The city center becomes more valuable as a trade center the more potential trading partners there are; the application development market grows and becomes more valuable to all users when there are more users who use the Internet or wireless communications more often. Efforts to perfectly calibrate the price of using the infrastructure so as to maximize both (a) the efficient utilization of the infrastructure at any point, including congestion peaks and (b) the positive externalities associated with high usage require enormous amounts of information, about all users, and about all possible combinations of users and uses that might benefit from meeting each other. Given imperfect information and transactions costs, it is practically impossible to maximize on both dimensions. Where we have seen infrastructures with very large positive externalities, like roads and navigable waters or the Internet, we have seen that tension resolved in favor of growth in the system as a whole through symmetric universal open access to the infrastructure resource, rather than in favor of efficiency of utilization of that resource. Depending on the cost of provisioning and the risk of disinvestment, we have seen these symmetrically managed resources range from simple open access and minimal use rules, like navigable waters,

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[48] David C. Mowery, Richard R. Nelson, Bhaven N. Sampat, and Ardvis Ziedonis, *Ivory Tower and Industrial Innovation*, University-Industry Technology Transfer Before and After the Bayh-Dole Act (Stanford University Press 2004); Jason Owen-Smith and Walter W. Powell, Career and Contradictions: Faculty Responses to the Transformation of Knowledge and its Uses in the Life Sciences 10 *Research in the Sociology of Work* **1**09 (2001).

unlicensed spectrum, or the Internet protocol, to owned and priced symmetric use models like common carriage, say, in telephony.

Uncertainty, freedom to operate, and exploration

Open access commons and property can also be interpreted as institutional mechanisms that represent significantly different information and motivation models. Property centralizes the point at which information and incentives necessary to determine the access, use, management, and disposition of a given resource in a single entity by giving that entity asymmetric power to determine who will get to access or use the resource, at what time, and for what purposes. The defining feature of commons is that there is no such asymmetric power. Instead, the resource is subject to a set of symmetric rules concerning access, use, extraction, and management. The absence of asymmetry removes the owner as a focal point for transactions and as the coordinating mechanism for competing claims on the resource. The symmetry allows diverse users the freedom to operate without transacting, within the symmetric constraints and subject to the congestion characteristics of the resource. As in the case of property and unlike regulatory decisions, information is gathered and processed by decentralized actors. Unlike the case of property, information gathered by these decentralized actors is not collated in a single decision point. Rather, diverse actors act upon information they have or exchange without the need to translate it into a universally understood expression (currency, for example) that compares competing uses and clears them.

Where the level of uncertainty is such that freedom of action (to adapt to changed circumstances) is an important desideratum, in some cases more than security in holdings (whose value and utility are part of the uncertainty) and power to appropriate outputs directly through exclusion (whose coming into being is part of the uncertainty)—we need, and find ubiquitously around us, both commons and property. On this analysis, with perfectly frictionless markets under perfect information, we wouldn't need commons. But this is no more relevant than saying that with perfectly selfless individuals under perfect information and frictionless social exchange we wouldn't need property. Given imperfect markets, imperfect information, diversely motivated individuals, and imperfect systems of social cooperation and exchange, some mix of property and commons is necessary for reasonable planning and pursuit of goals. This is from the private-returns perspective, setting aside collective goals like efficiency and growth, and explaining the widespread adoption of commons-based practices (like FOSS) even in the presence of property-based alternatives. From an individual agent's perspective, having a mix of resources—some commons, some property—will increase his or her utility over time, given imperfect markets, persistent uncertainty, and change.

The histories of spectrum commons and the Internet protocol offer nice illustrations. The combination of doubling of computation capacity every 18 months for decades, coupled with the global reach of the innovation system and its escape from the confines of a few well-known labs, like Bell Labs, created a rate and range of change that led to true uncertainty (as opposed to risk, where we know the range of outcomes and distribution of probabilities) in innovation practices that depended on computation (whose innovation rate caused uncertainty, but was not itself uncertain, and has not been managed in a commons) and communication as core resources. TCP/IP, the core internet protocol, implemented an "end-to-end" design principle that effectively refused to optimize for any particular function within the network, and required all applications to take care of themselves—that is, solve whatever higher level functions and optimization they required without making any demands on the network design itself. This design choice sacrificed optimization and efficiency of a known set of applications (e.g., voice or real-time streaming) in exchange for high flexibility and decentralization of the capacity to innovate. It meant that when four clever Israeli programmers figure out instant messaging, or four Estonian programmers figured out a better voice codec, they did not need to ask permission from a network operator, they did not require the change of network design that would still have to accommodate hundreds of other applications developed by others, but instead could simply design ICQ, the grandfather of instant messaging, or Skype, respectively, to do all of its work on the end user devices, and send through the network only the minimal simple packets the network was designed to receive and route. ICQ launched the Israeli high tech startup culture, but at the time, came out of nowhere. As for Skype, while the idea of video telephony had been around for decades, Skype's solution of using a modified peer-to-peer network that was built initially on an architecture that its creators had originally developed for the KaZaa peer-to-peer file sharing network, using end user nodes to relay packets that had no quality of service assurance in the network. The approach would have been treated as a pipe dream within the telephony engineering system before it was successfully introduced. The end-to-end, open access architecture of the Internet allowed for hundreds, or thousands, of low cost experiments in this and related fields to be run, implemented, and fail in a fully decentralized form until one or a few of them resulted in a superior solution. The same can be said of all the major innovations on the Internet—from Berners' Lee innovation of the World Wide Web, through the browser, the search engine, to the social network and the cloud storage company—these were all the results of extensive experimentation that depended on the open access commons model of the Internet and came out as the winning solution among many parallel efforts of exploration in the face of a rapidly changing and highly uncertain innovation challenge.

Similarly, in open access spectrum, we saw diverse companies develop diverse products to take advantage of open access spectrum bands, mostly WiFi but also other ISM bands, in a way that dramatically outpaced innovation by those few carriers who owned spectrum. In areas as diverse as smart grid communications systems, medical device wireless communications, or inventory management, the more cumbersome carriers that depended on proprietary spectrum allocations failed to keep up with the diverse range of innovative companies that relied on the commons.[49] Ultimately, even the carriers themselves ended up turning to the commons to carry a majority of their wireless data requirements. When presented with major spikes in its network after introduction of the iPhone, AT&T had major congestion problems with its mobile data network. It could have gone to the secondary spectrum markets set up by the Federal Communications Commission (FCC) a few years earlier, where it could have leased the additional capacity in a spot market. It did not. Instead, it combined a long-term proprietary strategy—seeking to purchase licenses from Qualcomm—with a short-term, more dynamic solution that was based on the commons. AT&T invested in WiFi hotspots and encouraged users to off-load traffic to their home and public WiFi spots. SFR in France, the second-largest mobile provider and third-largest home broadband provider, went one further and harnessed all of its home broadband subscribers—about 22 percent of the French market—to become WiFi load-balancing points for all their mobile data subscribers. WiFi off-loading by carriers has become the norm, carrying anywhere from 35 percent to 65 percent of mobile data.[50]

More generally, we can say that the more diverse, uncertain and rapidly changing the environment, the harder it is to codify the value of resources, uses, and outcomes, and the more attractive the freedom of action associated with having a resource in the commons is to these users. The symmetric constraints coupled with a general privilege to use the resource under these constraints mean that the need for transactions at the margin is eliminated, and with it transaction-cost barriers: strategic behavior of platform or essential-facilities owners, imperfect information with its widespread risk of unmatched offer-ask differences as a user seeks to obtain a sufficient flow of the resource, and so forth. The commons can be said to have a private option value to users whose price is (a) the reduced certainty of availability of a stated quantity of the resource as is available in markets, itself a function of how perfect or imperfect the relevant market is; (b) the lost appropriation opportunity from not having the resource controlled in a proprietary form, relative to non-exclusion based forms of appropriation that remain available without exclusion from the resource; and (c) the cost differential between the desired use in the market, given its imperfections and the cost of using the commons. The greater the background uncertainty as to the required quantity or quality of the resource and the market imperfections, the higher the option value—that is, the more of

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[49] Benkler, Open Wireless vs. Licensed Spectrum,.

50 See id at 103. The scale and scope of use, rather than the precise numbers, are what is important for purposes of this Review.

the benefits of property an agent would be willing to forgo in exchange for the greater flexibility offered by commons, within its known constraints.

Uncertainty is connected to one additional dimension of the economic advantage of open access commons. Different tasks are more or less amenable to the diverse motivations individuals bring to their actions. The better defined, more routine, a task, the easier it is to specify the desired level and quality of effort, to monitor the outcome and connect it to performance, and to therefore subject the behavior to reward and punishment on a standard incentives model. The more a desired outcome depends on initiative, tacit knowledge, insight or creativity, the more uncertain a task environment, and the more the worker needs to continuously examine, explore, innovate, adapt, and apply diverse forms of effort to the task, the harder it is to subject performance to monitoring, or to accurately price effort. As a result, intrinsic motivations become more important, and price-driven performance is harder to apply well. This different helps explain why Mertonian science takes over from managerial models as the explored knowledge space becomes less known; why industrial labs that are oriented towards generating big innovation steps create bubble relatively protected from managerial control, like Bell Labs, Xerox Labs, etc., and why entrepreneurial firms tend to cluster around universities which are excellent institutions for harnessing a range of motivations, from the pleasure of inquiry, through status, to freedom and flexibility over time and area of application. Where resources are subject to open access commons, they more readily lend themselves to models that do not tie use directly to payment. Agents who seek to operate on non-priced motivations can access the resources without concern for the ways in which their use could be translated into enough revenue to secure continued access to the resource. The success of commons-based strategies in areas like software development, consumer reviews, video creativity, or factual writing reflects precisely the freedom to operate on non-monetary motivations permitting the development of highly diverse creative and innovative practices.

4. *Types of open access commons*

The family of institutional arrangements that fall under the category of open access commons is defined by its use of symmetric use privileges, rather than asymmetric exclusive rights, as the core allocation mechanism. The primary branches in the family tree depend on the provisioning of the resource and the governance of the symmetric use privileges.

Table 1 offers an overview of the members of the open commons family and their exclusive property parallels. The table reflects four major provisioning systems—government, market, social, and natural—and four major governance approaches: state, property and contract, social norms, and no constraint. Each cell is divided into two: a light-gray shaded subcell where access to the resource is available to an open class on nondiscriminatory terms, and a black-shaded subcell where asymmetric exclusion is the organizing principle. The traditional antipodes (market, state) are represented by the categories of market-provisioned, property- and contract-governed, asymmetric exclusivity subcell (hot dogs, homes, and so on), and the state-provisioned, state-regulated, asymmetric exclusivity subcell (military bases, food stamps). Classic public goods are represented in the state-provisioning, no constraint cell (lighthouses). The dominant modes of commons that serve as the foundation of commercial, industrial economies fall in the nonexclusivity subcells of the state- and market-provisioning cells. These can be subject to state regulation (highways, public utilities, mass transit when state provisioned, or common carriers, privately held utilities, or unlicensed wireless bands when market provisioned), or no constraint (open government data, or formerly IP protected materials now in the public domain). The more exotic phenomena that have developed in networked society—free software, both commercial and purely socially produced—occupy the subcells of social provisioning, mostly with no asymmetric exclusivity, while many of the CPRs studied by the Ostrom school occupy both the symmetric nonexclusivity (for uses within the CPR) and asymmetric exclusivity (for the relations between insiders and outsiders in CPRs) subcells of social norms-organized, socially produced goods.

TABLE 1. COMMONS-BASED/OPEN CLASS SYMMETRIC ACCESS AND USE AND PROPERTY-BASED/EXCLUSION GOVERNANCE MODELS ORGANIZED BY MODE OF PROVISIONING.

Governance Provisioning	State Regulation	Property and Contract	Social-Cultural Norms	No Constraint
State: Tax, Bonds, Fees	Highways; public utilities; water; mass transit	Null (if universal symmetric access right, then law, not contract, allocates)	Peer review for publicly funded science not patented; parks; city squares; sidewalks	Lighthouses; government data: weather, labor/GDP measurements
	Military bases; food stamps	Government contracts	Publicly funded science that results in patents	Null
Markets: Direct payment, Indirect appropriation	Common carriers; “private” public utilities; unlicensed wireless bands	Broadcast reception (provision in market, but equal privilege to use); GPL/BSD software by firms (for example, Android)	Street performers; online musicians; voluntary compliance systems	Cultural materials & innovation originally commercial now in the public domain
	Automobile safety standards; zoning	Hot dogs; homes; personal computers; IP goods in coverage	Effort in high commitment organizations	Null
Social: Labor and goods, Donations	Solid organ donations	Contractually reconstructed commons; BSD, GPL? CC-BY; CC-SA?; CC-NC	CPRs inside, if need provisioning: for example a dam; von Hippel innovation; Wikipedia editing; much CBPP; GalaxyZoo; Foldit; culturally constructed commons	TCP/IP; the web; WiFi standards; much CBPP outputs; Wikipedia reading
	Health regulation applied to church day care	Enrollment in socially provisioned services	CPRs on the outside; Alicante irrigation system	Null
Nature	Pollution controls; national parks; fisheries	Privately created open nature preserves	CPRs that require allocation: for example, pastures	Air inhalation; Open Ocean transit
	Tradeable permits	Private recreation parks: for example, hunting lodges	CPRs from the outside	Null

5. Conclusion

This chapter was intended to familiarize readers with the literature on open access commons and the factual prevalence open access commons in contemporary advanced economies. Contrary to the tragedy of the commons fable, open access commons are in fact ubiquitous in modern, complex economies, and play a critical role in making market economies function.

Open access commons is not a single institution, but is a family of institutional arrangements. The core defining feature of the family is that its subtypes all apply an institutional model that provides symmetric use privileges to an open general class of users, rather than assigning an asymmetric exclusion right to an individual or known class of individuals, as do private property, club goods, or common property regimes. Open access commons have emerged through choice in markets, social arrangements, or public policy, even where earlier property-based institutions already existed. This has largely happened where use of the resource involved high positive externalities that cannot be internalized without substantial loss of total welfare; where innovation and exploration using the resource as input is particularly valuable, so that the innovation effects of permitting everyone to explore with productive uses of the resource dominate the efficiency effects of maintaining more controlled use for congestion avoidance; and where the resource is useful for a range of uses, including socially motivated use, which is unlikely to be able fully to express its social value if forced to be monetized.

The economic theory of open access commons as a general theoretical problem is still in its infancy. Substantial work has been done on common property regimes, on information commons, or the public domain vs. patents and copyrights, on the Internet protocol and end-to-end innovation, and on wireless spectrum regulation. There nonetheless remains substantial work to be done to synthesize these diverse forms of open access commons and explain at a more general level how these diverse commons interact with property to offer a more comprehensive theory of market economies and societies use of these two families of institutions. Even if the outline of the theoretical explanations available to date are unpersuasive to the reader, the fact of the large role of open access commons demands that we offer better theories, rather than that we largely ignore the commons and continue to imagine that property is the interesting core, and commons a negligible periphery.