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An Economic Theory of Infrastructure and Commons Management

Brett M. Frischmann

Article

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Brett M. Frischmann†

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† Assistant Professor of Law, Loyola University Chicago School of Law. I would like to thank Larry Lessig for the insights in his Reply to this Article. As the reader will see, this Article draws inspiration from Professor Lessig's prior work. For comments on earlier versions of this paper, I would like to thank Kevin Bowman, Mike Carrier, Julie Cohen, David Driesen, Shubha Ghosh, Rita Heimes, Cynthia Ho, Mark Lemley, Jack Lerner, Larry Lessig, Doug Lichtman, Mike Madison, Steve Salop, Stephanie Stern, Kathy Strandburg, Spencer Waller, Christopher Yoo, and participants in the following: Conference, Of Fish and Forests, Notions and Potions: Managing Access to Natural Resources and Scientific Research in the Twenty-First Century, University of Maine School of Law's Marine Law Institute and Technology Law Center; Faculty Workshop, University at Buffalo School of Law and the Baldy Center for Law and Social Policy; Stanford Law School Center for Internet and Society Speakers Series, Stanford Law School; Conference, Intellectual Property, Sustainable Development, and Endangered Species: Understanding the Dynamics of the Information Ecosystem, Michigan State University-Detroit College of Law; the 2004 Law and Society Association Annual Meeting; the Fourth Annual Intellectual Property Scholars Conference; the Works-in-Progress Intellectual Property Colloquium, Boston University School of Law; and the Thirty-Second Research Conference on Communication, Information and Internet Policy, the National Center for Technology & Law, George Mason University School of Law. I also thank Robyn Axberg, Atanu Das, and Joe Sanders for excellent research assistance. Finally, I thank the editors of the *Minnesota Law Review* for their contribution to this piece. Research for this Article was supported by summer research grants from the Loyola University Chicago.

The open access (commons) versus private control debate is raging. The debate takes place in a number of fields, including the intellectual property and cyberlaw literatures, as well as in broader public debates concerning propertization, privatization, deregulation, and commercialization of areas as diverse as communication networks, government services, national forests, and scientific research. On the private control side, there is robust economic theory supporting the market mechanism with minimal government regulation. In contrast, advocates of open access frequently call for protecting "the commons." The theoretical support for this prescriptive call, however, is underdeveloped from an economics perspective. In fact, many who oppose propertization, privatization, deregulation, and commercialization view the field of economics with sincere suspicion and doubt.

This Article embraces economics and develops a theory of infrastructure that better explains why, for some classes of important resources, there are strong economic arguments for managing and sustaining the resources in an openly accessible manner. This approach differs from conventional analyses by focusing extensively on demand-side considerations and fully exploring how infrastructure resources generate value for consumers.

Three key insights emerge from this demand-side, value-creation-focused analysis. First, infrastructure resources are fundamental resources that generate value when used as inputs into a wide range of productive processes. Second, the outputs from these processes are often public and nonmarket goods that generate positive externalities that benefit society. Third, managing infrastructure resources in an openly accessible manner may be socially desirable when it facilitates these downstream activities.

Part I provides an overview of this Article, situating the analysis within existing scholarship and explaining the connection between infrastructure and commons management. Section A explains that traditional infrastructure resources are generally managed in an openly accessible manner because such resources present a "comedy of the commons" rather than a "tragedy of the commons." Section B then explains how commons can best be understood as a resource management principle—commons management—that can be implemented through a variety of institutions.

Part II explores economic characteristics of infrastructure, focusing first on the traditional economic concepts used in welfare analyses of infrastructure resources and then delving deeper to better understand societal demand for these resources. This Part develops a new theory of infrastructure.

Putting theory into context, Part III illustrates how, economically, certain environmental and informational resources behave as infrastructure. This Part focuses specifically on lakes and basic research to explain how these resources are fundamental inputs into a wide range of productive activities that yield positive externalities that benefit society. Granting private ownership of such resources may lead to social costs that evade observation or appreciation in conventional economic analysis. The basic problem with relying on the market mechanism to allocate access to such resources is that the mechanism has an inherent bias for outputs that generate observable and appropriable returns. Part III also discusses briefly how environmental regulation and intellectual property law reflect society's desire to sustain common access to environmental and intellectual infrastructure resources.

Finally, Part IV applies this framework to the debate over network neutrality and the future of the Internet's end-to-end architecture. At the heart of this debate is whether the Internet should retain its current end-to-end design and thereby continue to be managed as a commons. Ultimately, the outcome of this debate will determine whether the Internet will continue to operate as a mixed infrastructure, or whether it will evolve into a commercial infrastructure optimized for a particular class of outputs—the delivery of commercial content for consumption. This Part argues that the current debate is skewed because it focuses myopically on neutrality, competition theory, and innovation. Because much more is at stake than the current debate reflects, a new lens is needed.

The Internet is a fundamental public and social infrastructure that is "[t]ransforming [o]ur [s]ociety."[1] The transformation is similar to transformations that we have experienced in the past with other infrastructure,[2] yet it is occurring in a more rapid, widespread, and dramatic fashion.[3] The Internet is quickly becoming integral to the lives, affairs, and relationships of individuals, companies, universities, organizations, and governments worldwide, and it is having significant effects on fundamental social processes and resource systems that generate value for society. Commerce, community, culture, education, government, health, politics, and science are all information- and communications-intensive systems that the Internet is transforming. The transformation is taking place at the ends, where people are empowered to participate and are engaged in socially valuable activities. Applying the demand-side theory of infrastructure to the network neutrality debate does not solve the problem or provide a definitive answer to the tough choices that lie ahead. The theory, however, brings into focus the social value of sustaining Internet infrastructure in an openly acces-

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1. PRESIDENT'S INFO. TECH. ADVISORY COMM., INFORMATION TECHNOLOGY RESEARCH: INVESTING IN OUR FUTURE 11 (1999) [hereinafter INVESTING IN OUR FUTURE], *available at* http://www.itrd.gov/pitac/report/pitac_report.pdf.

2. *Id.* at 11–20.

3. *Id.* at 11 ("As we approach the new millennium, it is clear that the 'information infrastructure'—the interconnected networks of computers, devices, and software—may have a greater impact on worldwide social and economic structures than all networks that have preceded them."); *id.* at 35 ("Within the next two decades, the Internet will have penetrated more deeply into our society than the telephone, radio, television, transportation, and electric power distribution networks have today. For many of us, the Internet has already become an integral part of our daily lives.").

sible manner, and strongly suggests that the benefits of open access (costs of restricted access) are significantly greater than the current debate reflects.

I. FROM INFRASTRUCTURE TO COMMONS MANAGEMENT

Scholars in a number of fields have been struggling to determine whether particular resources should be managed as "commons," which, for purposes of this Article, means that the resource is openly accessible to all within a community regardless of the entity's identity or intended use.[4] Perceived as the antithesis of private property and an alternative to government ownership or control,[5] commons have become the centerpiece of a broader debate over public access to and private control over various resources.[6] While there is significant interest in the concept of managing resources as commons, there is considerably less explanation of how to decide whether doing so would be normatively attractive in particular cases with respect to particular resources.

In *The Future of Ideas*, for example, Lawrence Lessig made clear his belief that American society must make difficult decisions between freedom and control.[7] We must decide, Lessig reminds us, between *freedom* and *control*, between *open access* and *restricted access*.[8] These choices must be made with respect to resources—the environment, information, culture, the Internet, and so on. Lessig recognizes that these questions do not have simple answers. Rather, the choice is difficult because it is

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4. *See infra* Part I.B (defining commons and explaining my approach).

5. *See* Yochai Benkler, The Commons as a Neglected Factor of Information Policy 2 (Sept. 1998) (working draft) (analyzing the commons as "a third, neglected, institutional approach," distinct from "direct government intervention and privatization"), *at* http://www.benkler.org/commons.pdf.

6. *See* Joseph Farrell & Philip J. Weiser, *Modularity, Vertical Integration, and Open Access Policies: Towards a Convergence of Antitrust and Regulation in the Internet Age*, 17 HARV. J.L. & TECH. 85, 88 (2003) ("The open access question is even more ubiquitous than it may first appear, as policymakers and commentators often use different terms to describe the issue. Antitrust commentators discuss the 'primary' (or 'bottleneck') market and the 'secondary' (or 'complementary') market. In telecommunications, participants talk of 'conduits' and 'content.'").

7. LAWRENCE LESSIG, THE FUTURE OF IDEAS: THE FATE OF THE COMMONS IN A CONNECTED WORLD 11–16 (2001) [hereinafter LESSIG, THE FUTURE OF IDEAS].

8. *Id.* at 14–15.

not really a dichotomous choice.[9] We need both freedom and control. For example, some types of information should be controlled, other types of information should be free for public use, and still other types should be somewhat controlled and somewhat openly accessible, depending upon how the information is used. The tricky question, then, is to figure out how to determine whether particular resources should be managed in an openly accessible manner, and if so, to what degree.

Throughout his book, Lessig details numerous examples of "free" common resources that benefit society and also illustrates the ongoing enclosure of many of these resources.[10] He demonstrates how the Internet has altered the landscape and enabled freedom, and offers a number of proposals for stemming the rising tide of enclosure. The book is a wonderful call to arms and is intellectually rich with theory, applications, and illustrative examples. Yet it remains unclear how to make the choices Lessig asks us to make, not only from a procedural standpoint (as voters or consumers, for example) but also from a normative standpoint. This Article takes a step in that direction.[11]

Utilizing an economic approach,[12] I define a set of important resources that are particularly attractive candidates for commons management, specifically infrastructure.[13] My thesis

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9. *Id.* at 14 ("The choice is not between all or none.").

10. *Id. passim.* On the enclosure of public resources, see DAVID BOLLIER, PUBLIC ASSETS, PRIVATE PROFITS: RECLAIMING THE AMERICAN COMMONS IN AN AGE OF MARKET ENCLOSURE (2001), *available at* http://www.bollier.org/pdf/PA_Report.pdf.

11. Lessig certainly points in the direction I am heading: "What has determined 'the commons,' then, is not the simple test of rivalrousness. What has determined the commons is the *character of the resource* and how it *relates to a community*. . . . [T]he question a society must ask is which resources *should be*, and for those resources, *how*." LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 21; *see infra* Part II.B–C (analyzing infrastructure in terms of nonrivalrousness and the manner in which the resource is used to create value).

12. In terms of figuring out what is normatively attractive, I adopt an economic approach focused on maximizing social welfare. I recognize that such an approach has its limits and that alternative approaches exist. For a paper that focuses on freedom and expressly adopts the First Amendment as its guiding normative principle, see Yochai Benkler, Property, Commons, and the First Amendment: Towards a Core Common Infrastructure 26 (Mar. 2001) (White Paper for the First Amendment Program, Brennan Center for Justice at NYU Law School) [hereinafter Benkler, Core Common Infrastructure], *available at* http://www.benkler.org/WhitePaper.pdf.

13. Prominent scholars, such as Yochai Benkler and Lawrence Lessig, have relied on analogies to traditional infrastructure such as highways in support of their prescriptive call for managing other resources in an openly

is that if a resource can be classified as infrastructure according to the economic criteria set forth in Part II of this Article, then there are strong economic arguments that the resource should be managed in an openly accessible manner.[14] Before developing these arguments, however, it is necessary to explain briefly what I mean by "infrastructure" and "commons management," and why I focus on these concepts.

A. INFRASTRUCTURE

The term "infrastructure"[15] generally conjures up the notion of physical resource systems made by humans for public consumption.[16] A list of familiar examples includes: (1) *trans-*

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accessible manner. *See, e.g.*, LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 77, 87, 244; Yochai Benkler, *Overcoming Agoraphobia: Building the Commons of the Digitally Networked Environment*, 11 HARV. J.L. & TECH. 287, 388–89 (1998) [hereinafter Benkler, *Overcoming Agoraphobia*]. Both Benkler and Lessig have focused on resources associated with our "networked information economy." *See, e.g.*, Yochai Benkler, Lecture, *Freedom in the Commons: Towards a Political Economy of Information*, 52 DUKE L.J. 1245, 1251 (2003) [hereinafter Benkler, *Freedom in the Commons*].

14. In a series of publications, Benkler has advanced a powerful set of arguments in favor of developing a "core common infrastructure—a set of resources necessary to the production and exchange of information, which will be available as commons." Benkler, *Freedom in the Commons*, *supra* note 13, at 1273 (emphasis omitted); *see also* Yochai Benkler, *Coase's Penguin, or, Linux and* The Nature of the Firm, 112 YALE L.J. 369 (2002) [hereinafter Benkler, *Coase's Penguin*]; Yochai Benkler, *From Consumers to Users: Shifting the Deeper Structures of Regulation Toward Sustainable Commons and User Access*, 52 FED. COMM. L.J. 561 (2000) [hereinafter Benkler, *From Consumers to Users*]; Yochai Benkler, *The Battle over the Institutional Ecosystem in the Digital Environment*, COMM. ACM, Jan. 2001, at 84 [hereinafter Benkler, *Battle over the Institutional Ecosystem*]; Benkler, Core Common Infrastructure, *supra* note 12. As discussed below, many of the arguments advanced in this Article are complementary to those advanced by Benkler.

15. *See* BLACK'S LAW DICTIONARY 784 (7th ed. 1999) (Infrastructure: "The underlying framework of a system; esp., public services and facilities (such as highways, schools, bridges, sewers, and water systems) needed to support commerce as well as economic and residential development."); WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY OF THE ENGLISH LANGUAGE UNABRIDGED 1161 (1993) (Infrastructure: "[T]he underlying foundation or basic framework (as of an organization or a system) : substructure; esp : the permanent installations required for military purposes.") (emphasis omitted); *see also* WILLIAM MORRIS & MARY MORRIS, MORRIS DICTIONARY OF WORD AND PHRASE ORIGINS 309 (2d ed. 1988) (providing a historical account of how the term's meaning has evolved).

16. As I discuss below, seeing some natural resources as infrastructure helps explain intuitive connections between these resources and resources we commonly perceive as infrastructure. This classification also sets forth a normative basis for managing these resources in an openly accessible manner. *See infra* Part III.

portation systems, such as highway systems, railways, airline systems, and ports; (2) *communication systems*, such as telephone networks and postal services; (3) *governance systems*, such as court systems; and (4) *basic public services and facilities*, such as schools, sewers, and water systems. I refer to these resources as "traditional infrastructure."[17]

The economics of traditional infrastructure are quite complex.[18] This is reflected perhaps in the fact that economists sometimes refer to infrastructure "opaquely" as "social overhead capital."[19] As W. Edward Steinmueller observed:

> Both traditional and modern uses of the term infrastructure are related to "synergies", what economists call positive externalities, that are incompletely appropriated by the suppliers of goods and services within an economic system. The traditional idea of infrastructure was derived from the observation that the private gains from the construction and extension of transportation and communication networks, while very large, were also accompanied by additional large social gains. . . . Over the past century, publicly regulated and promoted investments in these types of infrastructure have been so large, and the resulting spread of competing transportation and communications modalities have become so pervasive, that they have come to be taken as a defining characteristic of industrialized nations.[20]

Not surprisingly, in addition to the study of the economics of regulation and natural monopolies in general, economists have focused their attention on the economics of infrastructure resources in these particular industries.[21] Further, economists have examined the role that infrastructure investment has on

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17. I consider the traditional economics of infrastructure below, and then develop an economic model of infrastructure that fits both traditional and nontraditional infrastructure. This model better explains why traditional infrastructure is generally managed in an openly accessible manner, and why nontraditional infrastructure should be treated similarly. *See infra* Part II.

18. A survey of the entire field of infrastructure economics is beyond the scope of this Article.

19. Kenneth Button, *Ownership, Investment and Pricing of Transport and Communications Infrastructure*, *in* INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT 147, 148 (David F. Batten & Charlie Karlsson eds., 1996).

20. W. Edward Steinmueller, *Technological Infrastructure in Information Technology Industries*, *in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 117, 117 (Morris Teubal et al. eds., 1996). Steinmueller explains that economists have come to recognize the importance of information-based infrastructure. *See id.*

21. *See* W. KIP VISCUSI ET AL., ECONOMICS OF REGULATION AND ANTITRUST chs. 11–15 (2d ed. 1992) (discussing the economics of various infrastructure resources).

economic development, particularly in the context of developing nations and their economic policies.[22]

Two generalizations about traditional infrastructure are worth noting.[23] First, the government has played and continues to play a significant and widely-accepted role in ensuring the provision of many traditional infrastructures. While private parties and markets play an increasingly important role in providing many types of traditional infrastructure (due to a wave of privatization as well as cooperative ventures between industry and government),[24] the government's position as provider, coordinator, or regulator of traditional infrastructure provision remains intact in most communities.[25]

Second, traditional infrastructures are generally managed in an openly accessible manner. They are managed in a manner whereby all members of a community who wish to use the resources may do so.[26] As Mark Cooper has noted, "[r]oads and highways, canals, railroads, the mail, telegraph, and telephone, some owned by public entities, most owned by private corporations, have always been operated as common carriers that are required to interconnect and serve the public on a nondiscriminatory basis."[27] This does not mean, however, that access is free. We pay tolls to access highways, we buy stamps to send letters, we pay telephone companies to route our calls across

22. *See generally, e.g.*, INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT *supra* note 19; SIDNEY M. LEVY, BUILD, OPERATE, TRANSFER: PAVING THE WAY FOR TOMORROW'S INFRASTRUCTURE (1996).

23. Of course, there are exceptions to these generalizations.

24. *See* LEVY, *supra* note 22, at 1, 16–17.

25. The rebuilding of Iraq brings this point into stark relief. The task of reconstructing and rebuilding a country's traditional infrastructure—its transportation, communication, governance, and basic service systems—is a tremendous task requiring centralized coordination and substantial investment. Note that building these infrastructure systems is a necessary precursor to many other productive activities.

26. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 19–25; Carol Rose, *The Comedy of the Commons: Custom, Commerce, and Inherently Public Property*, 53 U. CHI. L. REV. 711, 752 (1986) [hereinafter Rose, *The Comedy of the Commons*]; Benkler, Core Common Infrastructure, *supra* note 12, at 22–23, 47–48. *See generally* Rose, *supra*, at 723–49 (discussing the history of public access rights to various infrastructure resources such as roadways and waterways).

27. Mark Cooper, Making the Network Connection: Using Network Theory to Explain the Link Between Open Digital Platforms and Innovation 14–15 (working draft), *at* http://cyberlaw.stanford.edu/blogs/cooper/archives/network%20theory.pdf (last visited Jan. 20, 2005).

their lines, and so on.[28] Users must pay for access to some (though not all) of these resources. Nor does it mean that access to the resource is unregulated. Transportation of hazardous substances by highway or mail, for example, is heavily regulated. The key point is that the resource is openly accessible to all within a community regardless of the identity of the end-user or the end-use.[29]

As discussed below, managing traditional infrastructure in an openly accessible fashion makes economic sense.[30] Most economists agree that traditional infrastructure resources generate significant positive externalities[31] that result in "large so-

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28. LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 244 ("The government has funded the construction of highways and local roads; these highways are then used either 'for free' or with the payment of a toll. In either case, the highway functions as a commons."). Of course, as taxpayers, we ultimately foot the bill for the provision of many infrastructure resources. *See* CONG. BUDGET OFFICE, THE LONG-TERM BUDGET OUTLOOK 39 (2003), *available at* http://www.cbo.gov/ftpdocs/49xx/doc4916/Report.pdf; CONG. BUDGET OFFICE, THE ECONOMIC EFFECTS OF FEDERAL SPENDING ON INFRASTRUCTURE AND OTHER INVESTMENTS (1998), *available at* http://www.cbo.gov/ftpdocs/6xx/doc601/fedspend.pdf; Andrea Bassanini & Stefano Scarpetta, *The Driving Forces of Economic Growth: Panel Data Evidence for the OECD Countries*, *in* OECD ECON. STUD. NO. 33, at 9, 19 (2001).

29. In some industries, however, access to an infrastructure resource is priced at different rates for different classes of users. *See* Andrew Odlyzko, *The Evolution of Price Discrimination in Transportation and Its Implications for the Internet*, 3 REV. NETWORK ECON. 323 (2004). For example, telecommunications companies historically have treated businesses and individuals differently without much concern. *See id.* at 336–37. Others have noted that price discrimination may, at times, be justified since it provides producers greater flexibility to recoup their costs than do mandatory universal service regimes. *See generally* Christopher Yoo, *Rethinking the Commitment to Free, Local Television*, 52 EMORY L.J. 1579, 1623 (2003). For other resources (e.g., a lake), a particular type of use (e.g., pollution) is regulated in order to preserve open access for other types of uses (e.g., swimming, fishing, boating, and drinking water source, to name a few). *See infra* Part III.A.

30. *See infra* Part II.A (discussing the economics of traditional infrastructure).

31. The term "externality" means many things and has been a contested concept in economics for many years. *See* ANDREAS A. PAPANDREOU, EXTERNALITY AND INSTITUTIONS 13–68 (1994) (providing a detailed historical account of the term); Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. PAPERS & PROC. 347, 348 (1967) ("Externality is an ambiguous concept."). Basically, positive (negative) externalities are benefits (costs) realized by one person as a result of another person's activity without payment (compensation). Externalities generally are not fully factored into a person's decision to engage in the activity. *See* JAMES E. MEADE, THE THEORY OF ECONOMIC EXTERNALITIES: THE CONTROL OF ENVIRONMENTAL POLLUTION AND SIMILAR SOCIAL COSTS 15 (1973) ("An external economy (diseconomy) is an event which confers an appreciable benefit (inflicts an appreciable damage)

cial gains."[32]

Understanding *how* traditional infrastructures generate positive externalities and *why* such resources are managed in an openly accessible manner is an important first step in understanding why other resources should be managed in a similar fashion. The same rationale for managing traditional infrastructure in an openly accessible manner applies to other resources that behave in the same economic fashion as traditional infrastructure, even though they generally are not considered infrastructure.[33] I refer to such resources as "nontradi-

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on some person or persons who were not fully consenting parties in reaching the decision or decisions which led directly or indirectly to the event in question."), *discussed in* RICHARD CORNES & TODD SANDLER, THE THEORY OF EXTERNALITIES, PUBLIC GOODS, AND CLUB GOODS 39 (1996); Kenneth J. Arrow, *The Organization of Economic Activity: Issues Pertinent to the Choice of Market Versus Nonmarket Allocation*, *in* PUBLIC EXPENDITURE AND POLICY ANALYSIS 59, 67 (Robert H. Haveman & Julius Margolis eds., 1970) (defining externality as the absence of a functioning market), *discussed in* CORNES & SANDLER, *supra*, at 40–43. Arrow made clear the importance of understanding that the existence or nonexistence of externalities is a function of the relevant institutional setting, incentive structure, information, and other constraints on the decision making and exchange possibilities of relevant actors. *See* CORNES & SANDLER, *supra*, at 39–43.

32. Steinmueller, *supra* note 20, at 117.

33. This is the analytic step in much of the scholarship concerning commons that requires further development. Lessig considers a number of rationales for managing a resource in an openly accessible manner, *see* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 83–99, but he does not fully explore how open access to infrastructure resources generates social value. For example, relying on Carol Rose, Lessig explains first that the reason a "road is kept in the commons" is that "the opportunity for 'holdouts' would be too great if the road were private." *Id.* at 87. As a second example, he discusses a town square and suggests that, in both cases, the resources are managed in an openly accessible manner because it would be unfair to allow a private owner to capture these resources' value since their value increases as the number of users increases. *Id.* at 87–88. Private control in these situations is problematic for several reasons. First, private control might be inefficient if the owner decides to restrict access due to holdouts (strategic behavior). *Id.* Second, even without holdouts, private control might be inequitable because the owner would capture social surplus that ought to be distributed among the consumers who contributed to the value-creation. *Id.* Both of these points reflect valid concerns. The former, I think, is more problematic, although for various reasons in addition to complications arising from potential holdouts. *See infra* Part II. Lessig goes even further than Rose, suggesting that the argument for managing a resource in an openly accessible manner depends, in part, on the degree of uncertainty as to how the resource will be used. *See id.* at 88–89; *see also* Brett Frischmann, *Innovation and Institutions: Rethinking the Economics of U.S. Science and Technology Policy*, 24 VT. L. REV. 347 (2000) [hereinafter Frischmann, *Innovation and Institutions*] (making the same argument with respect to basic and applied research). I further develop this argument in this Article

tional infrastructure." A few examples of such resources include (1) *environmental resources*, such as lakes, the atmosphere, and ecosystems; (2) *information resources*, such as basic research, abstract ideas, and operating systems; and (3) *Internet resources*, such as interconnected computer networks and protocols that enable interconnection, interoperability, and data transfer. These resources also generate (or have the potential to generate) significant positive externalities that result in large social gains.

Carol Rose was the first to draw an explicit, causal connection between open access and these positive externalities.[34] In her path-breaking article, *The Comedy of the Commons: Custom, Commerce, and Inherently Public Property*, Rose explained that a "comedy of the commons" arises where open access to a resource leads to scale returns—greater social value with greater use of the resource.[35] With respect to road systems, for example, Rose considered commerce to be an

> interactive practice whose exponential returns to increasing participation run on without limit. . . . Through ever-expanding commerce, the nation becomes ever-wealthier, and hence trade and commerce routes must be held open to the public, even if contrary to private interest. Instead of worrying that too many people will engage in commerce, we worry that too few will undertake the effort.[36]

Critically, as Rose recognized, managing road systems in an openly accessible manner is the key to sustaining and increasing participation in commerce, and commerce is itself a

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with respect to both the type of use and the variance of possible uses. *See infra* Part II.

34. Rose, *The Comedy of the Commons*, *supra* note 26, at 723, 775–81. Harold Demsetz, however, came close. Demsetz suggested that "[c]ommunal property results in great externalities. The full costs of the activities of an owner of a communal property right are not borne directly by him, nor can they be called to his attention easily by the willingness of others to pay him an appropriate sum." Demsetz, *Toward a Theory of Property Rights*, *supra* note 31, at 355. Demsetz focused exclusively on negative externalities (external costs) and failed to appreciate that communal property can result in great positive externalities (external benefits) and that such a result can be socially desirable. *See id. passim*; Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, 82 TEX. L. REV. (forthcoming 2005) (manuscript at 17–25), *available at* http://ssrn.com/abstract=582602.

35. Rose, *supra* note 25, at 768–70.

36. *Id.* at 769–70; *see also* Louis P. Cain, *A Canal and Its City: A Selective Business History of Chicago*, 11 DEPAUL BUS. L.J. 125, 142–43 (1998) ("[A]s long as Lake Michigan remained a 'fixed fact,' every railroad or town that was built and every farm that was settled north and west of the city would only increase the trade and prosperity of Chicago." (quoting 1 A.T. ANDREAS, HISTORY OF CHICAGO FROM THE EARLIEST TIME TO THE PRESENT 40 (1884))).

productive activity that generates significant positive externalities.[37] Commerce is an excellent example of a productive use of roads that generates positive externalities and social surplus, but there are many others, such as visits to relatives or to state parks.[38] This Article builds upon Rose's important—but since underdeveloped—insight that certain resources ought to be managed in an openly accessible manner because doing so increases participation in activities, such as commerce, that yield scale returns.

This Article develops an economic model of infrastructure that fits both traditional infrastructure and nontraditional infrastructure.[39] This model better explains several key aspects of infrastructures, including the relationships between infrastructure resources and various downstream activities, how infrastructure resources generate value for society, why traditional infrastructure resources are managed in an openly accessible manner, and why certain nontraditional infrastructure should be managed in an openly accessible manner. This model serves both descriptive and normative purposes.

Errors of resource classification often infect analysis of legal and social institutions.[40] Too often, analysts classify an infrastructure resource as a public good, network good, or natural monopoly,[41] acknowledge that it is well understood that markets may fail to efficiently supply such goods, and then proceed to analyze the form of institutional intervention by the government to correct the failure, typically assuming that the de-

37. Rose, *The Comedy of the Commons*, *supra* note 25, at 723, 774–818.

38. *Cf.* Lewis M. Branscomb & James H. Keller, *Introduction* to CONVERGING INFRASTRUCTURES: INTELLIGENT TRANSPORTATION AND THE NATIONAL INFORMATION INFRASTRUCTURE 1 (Lewis M. Branscomb & James H. Keller eds., 1996) ("Over the past half century, the U.S. highway system has advanced regional and national economic development by enhancing access to markets for goods, services, and people. It has also provided direct quality-of-life benefits, by providing easier access to both work and leisure.").

39. I should note that I am not developing a formal mathematical model in this Article, although I may pursue such a model in separate work. My central objective is to develop a conceptual model firmly grounded in economic theory that sheds light on how infrastructure commons generate social value. I spell out my objectives in more detail in the text that follows.

40. *Cf.* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 2–3, 17–48) (arguing that real property rhetoric, theory, and rationale have infected intellectual property law and have placed too much emphasis on free riding).

41. *See infra* notes 77–85 and accompanying text; *infra* Part II.A (discussing these classifications).

gree of intervention should be minimal.[42] Market failure for infrastructure, however, is more complex than these classifications suggest. To understand and grapple with the additional demand-side complexity, it is necessary to reconceptualize infrastructure.

For both traditional and nontraditional infrastructure resources, analysts emphasize supply-side issues, typically cost recovery, and assume that the market mechanism will best generate and process demand information.[43] Economists (and regulators) generally focus on three types of supply-side issues: (1) excludability, (2) natural monopoly, and (3) anticompetitive behavior. Excludability relates to the costs of excluding nonpaying users. If these costs are high, then producers may undersupply because they are unable to prevent free riding.[44] The concept of a natural monopoly recognizes that for certain markets, it may be socially desirable to have a single producer, in which case government regulation may be necessary for a variety of reasons (e.g., to constrain monopoly pricing).[45] Anticompetitive behavior relates to industry structure and the risk of anticompetitive behavior by dominant firms.[46] These issues

42. Elsewhere, I have argued that the traditional "government intervention into the market" analysis is incomplete and perhaps biased towards market-oriented solutions to public goods, governance, and other social problems. *See* Brett Frischmann, *Privatization and Commercialization of the Internet Infrastructure: Rethinking Market Intervention into Government and Government Intervention into the Market*, 2 COLUM. SCI. & TECH. L. REV. 1, 2–6 (2001) [hereinafter Frischmann, *Internet Infrastructure*], *available at* http://www.stlr.org/cite.cgi?volume=2&article=1; *see also* Shubha Ghosh, *Deprivatizing Copyright*, 54 CASE W. RES. L. REV. 387, 397 (2003) (exploring the limits of the "market baseline" and its "assumption that private interest working through market transactions will lead to public good"); Neil Weinstock Netanel, *Copyright and a Democratic Civil Society*, 106 YALE L.J. 283, 306–11 (1996) (critiquing market theory in copyright law). *See generally* Richard R. Nelson, *Roles of Government in a Mixed Economy*, 6 J. POL'Y ANALYSIS & MGMT. 541 (1987) (explaining the limits of market failure analysis).

43. *See, e.g.*, Daniel F. Spulber & Christopher S. Yoo, *Access to Networks: Economic and Constitutional Connections*, 88 CORNELL L. REV. 885, 919, 921, 926 (2003) (assuming that if competitive markets can form, then "market prices [will] continue to be an accurate measure of value."). *But see* Patricia A. Champ, *Collecting Survey Data for Nonmarket Valuation*, *in* A PRIMER ON NONMARKET VALUATION 59, 59 (Patricia A. Champ et al. eds., 2003) ("The unique nature of environmental and natural resource amenities makes valuation a challenge in many respects. Prices reflect aggregate societal values for market goods but nonmarket goods lack an analogous indicator of value.").

44. *See infra* Part II.A (discussing nonexcludability).

45. *See infra* note 81 (discussing natural monopolies).

46. *See infra* Part II.D (discussing industry structure and the risk of anticompetitive behavior).

(and other related supply-side issues) are important but tell only half of the story.

In contrast to these supply-side concepts, this Article focuses on the demand-side issues. How and to what extent infrastructure resources generate value for society remain underexplored areas that warrant further attention. When economists and other observers focus on supply-side issues with respect to infrastructure resources, they fail to account for many critical demand-side considerations. Consequently, there is an incomplete evaluation of true social demand for infrastructure resources.[47] This problem distorts institutional analyses by discounting the social benefits (costs) of open access (restricted access) to infrastructure resources. As Judge Boudin reflected in *Lotus Development Corp. v. Borland International, Inc.*:

> Of course, the argument *for* protection is undiminished, perhaps even enhanced, by utility: if we want more of an intellectual product, a temporary monopoly for the creator provides incentives for others to create other, different items in this class. *But the "cost" side of the equation may be different where one places a very high value on public access to a useful innovation . . . . Thus, the argument for extending protection may be the same; but the stakes on the other side are much higher.*[48]

Infrastructure resources, in particular, constitute an important class of resources on which society should place "a very high value on public access."[49] Yet conventional economic analysis of many infrastructure resources fails to fully account for how the resources are used as inputs to create social benefits; thus, the analysis fails to fully account for the social demand for the resources.[50] Economists—as well as regulators

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47. *See* Frischmann, *Internet Infrastructure*, *supra* note 42, at 6, 54, 57–58, 69 (explaining that market demand for Internet infrastructure is but a fraction of social demand, even assuming that the market functioned at near perfection); *see also* Julie E. Cohen, *Copyright and the Perfect Curve*, 53 VAND. L. REV. 1799, 1809–14 (2000) [hereinafter Cohen, *Perfect Curve*] (making the same point in the copyright context); Julie E. Cohen, Lochner *in Cyberspace: The New Economic Orthodoxy of "Rights Management,"* 97 MICH. L. REV. 462, 539 (1998) [hereinafter Cohen, Lochner *in Cyberspace*] ("Many of these [positive externalities] are experienced as public goods and likely would be underproduced under a private-law regime of rights in digital works."). Cohen's observation reverberates throughout this Article; many infrastructure resources generate large positive externalities that are not captured fully by infrastructure suppliers or users and thus constitute social surplus.

48. Lotus Dev. Corp. v. Borland Int'l, Inc., 49 F.3d 807, 819 (1st Cir. 1995) (Boudin, J., concurring) (emphasis added).

49. *See id.*

50. The economics discipline certainly has the tools to analyze these demand-side issues, tools which I will use throughout this Article. My point is

and politicians—recognize that there is a tremendous demand for public infrastructure and that infrastructure plays a critical role in economic development, but exactly why there is demand, how it manifests, how it should be measured, and how it contributes to economic growth are not well understood.[51] Critically, many infrastructure resources act as inputs into a wide variance of socially valuable activities, including the production of public goods and nonmarket goods.[52] These activities generate significant social welfare gains that are generally associated with traditional infrastructure, yet underappreciated with respect to nontraditional infrastructure.[53]

The importance of this project may best be understood by way of comparison with network effects. There is a strong parallel between the objectives of this project and those of scholars analyzing network effects and their implications for economic, legal, and policy analysis. As Mark Lemley and David McGowan explained, network effects "refers to a group of theories clustered around the question whether and to what extent standard economic theory must be altered in cases in which 'the utility that a user derives from consumption of a good increases with the number of other agents consuming the good.'"[54]

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that economists have not employed these tools thus far.

51. *See generally, e.g.*, INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT, *supra* note 19; *cf.* Steven Shavell & Tanguy Van Ypersele, *Rewards Versus Intellectual Property Rights*, 44 J.L. & ECON. 525, 543 (2001) ("[T]he government's problem of determining rewards is made more difficult when the value of an innovation is in part that it leads to subsequent innovations."); John F. Duffy, *The Marginal Cost Controversy in Intellectual Property*, 71 U. CHI. L. REV. 37, 53 (2004) ("[I]t may be a much simpler matter to tell how many cars cross a bridge or how much electricity is consumed than to determine how often an idea is used.").

52. *See infra* Part II.A (defining and discussing public goods and nonmarket goods).

53. I recognize that this is a very strong claim that requires empirical support to verify. Yet there are significant difficulties in capturing the positive externalities generated by the downstream production of public goods and nonmarket goods in an empirical study. Economists have attempted to measure the social surplus generated by infrastructure resources, such as the National Highway System. Such studies, however, generally are limited in scope to macroeconomic measures, such as economic growth or increases in productivity within industrial sectors. *See, e.g.*, M. ISHAQ NADIRI & THEOFANIS P. MAMUNEAS, U.S. DEP'T OF TRANSP., CONTRIBUTION OF HIGHWAY CAPITAL TO OUTPUT AND PRODUCTIVITY GROWTH IN THE US ECONOMY AND INDUSTRIES (1998), *available at* http://www.fhwa.dot.gov/policy/gro98cvr.htm.

54. Mark A. Lemley & David McGowan, *Legal Implications of Network Economic Effects*, 86 CAL. L. REV. 479, 483 (1998).

Like resources that exhibit network effects, infrastructure resources perform economically in a manner that challenges conventional economics and warrants special consideration.[55] The impact of infrastructure theory may be even more profound than network theory because it is more far-reaching and touches more fundamental sets of resources that serve as the very foundation of most economies.

B. COMMONS AS RESOURCE MANAGEMENT

This Article uses "open access" and "commons" interchangeably to refer to the situation in which a resource is openly accessible to all users regardless of the users' identity or intended use of the resource.[56] This may be troublesome to property scholars accustomed to the important distinction maintained between open access and commons within property scholarship: Open access typically implies absolutely no ownership rights or property rights. No entity possesses the right to exclude others from the resource; all who want access can get access.[57] Commons, on the other hand, typically involves communal ownership (community property rights, public property rights, joint ownership rights, etc.), such that members of the relevant community obtain open access "under rules that may range from 'anything goes' to quite crisply articulated formal rules that are effectively enforced" and nonmembers can be excluded.[58] Recent scholarship has analyzed hybrid regimes, such

55. Infrastructure effects are distinct from network effects, however. *See infra* Part II.D. Both types of economic effects have the potential to generate demand-side externalities, but the externalities attributable to network effects are more likely to be internalized by network providers than the externalities attributable to infrastructure effects.

56. *Cf.* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 19–20 (adopting a similar definition); ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 1–7 (1990) (same); Joanna Burger et al., *Introduction* to PROTECTING THE COMMONS: A FRAMEWORK FOR RESOURCE MANAGEMENT IN THE AMERICAS 1, 1–6 (Joanna Burger et al. eds., 2001) (same); BOLLIER, *supra* note 10, at 2–3 (same); *see also* Estate of Martin Luther King, Jr., Inc. v. CBS, Inc., 194 F.3d 1211, 1214 (11th Cir. 1999) (employing a nearly identical definition of a "general publication" in U.S. copyright law: General publication occurs "when a work was made available to members of the public at large without regard to their identity or what they intended to do with the work").

57. Charlotte Hess & Elinor Ostrom, *Ideas, Artifacts, and Facilities: Information as a Common-Pool Resource*, 66 LAW & CONTEMP. PROBS. 111, 121–22 (2003).

58. Yochai Benkler, *The Political Economy of Commons*, UPGRADE, June 2003, at 6, 6–7. As Benkler explains:

as semicommons, which have attributes of both private and common property.[59]

For now, put aside these distinctions between property regimes and simply focus on the accessibility rule—that the resource is open to users regardless of the user's identity or intended use. In other words, put aside considerations of ownership and regulation, and view open access (or common access or public access) as a resource management decision, which might be made privately or publicly, politically or economically, through property rights, regulation, or some hybrid regime, depending on the context.[60]

I intentionally abstract from the institutional *form* (property rights, regulations, norms, etc.) to focus on a particular institutional *function* (opening or restricting access). Tying form and function together obscures the fact that access can be provided for or restricted by a variety of institutional forms, which are often mixed (property and regulation, private and communal property, etc.), and not necessarily through one particular form of property rights.[61] For example, as Parts III and IV will demonstrate, environmental, information, and Internet commons are sustained through very different sets of institutional

> Commons are a particular type of institutional arrangement for governing the use and disposition of resources. Their salient characteristic, which defines them in contradistinction to property, is that no single person has exclusive control over the use and disposition of any particular resource. Instead, resources governed by commons may be used or disposed of by anyone among some (more or less well defined) number of persons, under rules that may range from "anything goes" to quite crisply articulated formal rules that are effectively enforced.

Id. at 6.

59. *See generally* Robert Heverly, *The Information Semicommons*, 18 BERKELEY TECH. L.J. 1127 (2003); Henry E. Smith, *Semicommon Property Rights and Scattering in the Open Fields*, 29 J. LEGAL STUD. 131 (2000).

60. *See* Frischmann, *Internet Infrastructure*, *supra* note 42, at 59. To elaborate:

> [T]he public domain is a form of social infrastructure, an open-access management or governance regime for resources, that is socially constructed from customs, norms, rules, laws, etc. Resources that "fall within" the public domain, and thus are "governed by" an open-access regime, are openly available to the public without restriction; no one lays claim to such resources—not the government or private parties. Everyone is "equally privileged" to use the resource.

Id. (footnotes omitted).

61. *See* Heverly, *supra* note 59, at 1130–31; *cf.* Farrell & Weiser, *supra* note 6, at 95 ("[M]odularity can arise as an internal management system, as a self-governing organization of a market, or as a result of public policy decisions.").

arrangements. Ultimately, the optimal degree of openness or restrictiveness depends upon a number of functional economic considerations related to the nature of the resource in question, the manner in which the resource is utilized to create value, institutional structures, and the community setting.

The openness or restrictiveness of access to a resource and the related terms of access can be analyzed as characteristics of the resource itself. For example, does society demand an open infrastructure, a closed infrastructure, or something in between? Does society demand an infrastructure designed to be neutral to the types of end-uses or end-users that may require access?[62] Part IV later explores these issues in more detail in the context of the ongoing debate over network neutrality and the future of the end-to-end architecture of the Internet.

The key points, then, are that: (1) accessibility or excludability conditions are generally contingent upon human decisions about how to manage the underlying resource, and (2) demand for access to the underlying resource depends upon how the resource may be used to create value. For example, demand for access to a road connecting A to B does not depend upon whether the road is privately or publicly owned. Demand depends upon individuals' desire to get from A to B, which depends, of course, on what can be done at the destination. With respect to supply-side issues, private or public ownership mat-

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62. More generally, this subject brings to mind the intimate relationship between inherent and socially constructed characteristics of resources. *See* Mike J. Madison, On Things 80–81 (2005) (working paper, on file with author). *See generally* Dan L. Burk, *DNA Rules: Legal and Conceptual Implications of Biological "Lock-Out" Systems*, 92 CAL. L. REV. 1553 (2004); Dan L. Burk, *Lex Genetica: The Law and Ethics of Programming Biological Code*, 4 ETHICS & INFO. TECH. 109 (2002). For example, it is one thing to say that information is inherently a public good because, technically and abstractly speaking, in its purest form, information is both nonrivalrous and nonexcludable. *See infra* Part II.A (exploring these concepts). However, one might dismiss such abstract talk of inherent characteristics as technically correct but practically irrelevant because, in the real world, we regularly alter the characteristics of information through social constructs like intellectual property and technology. These alterations facilitate exclusion, artificially create scarcity, and make some real-world markets work. *See infra* Part III.B (discussing intellectual property as a socially-constructed means for facilitating exclusion). These alterations may correct certain types of market failure but exacerbate others.

Of course, the fact that social constructs often mask inherent characteristics does not make discussion of inherent characteristics irrelevant. Rather, we must understand both the inherent and socially constructed features of resources. This Article and the infrastructure theory that it lays out focus on social demand for openly accessible infrastructure resources.

ters. For example, private and public entities will fund construction and maintenance of the roads in different manners, and if demand exceeds supply and leads to congestion on the road, public and private owners may respond differently. The difference between public and private ownership therefore matters, but primarily with respect to evaluating *how* demand will be satisfied.

For purposes of this Article, the term "commons" will refer to a de jure or de facto management decision "governing the use and disposition of" a resource.[63] Environmental, informational, and Internet resources are not inherently commons, in the same way that an apple is not inherently private.

There are many ways in which a resource can come to be managed in an openly accessible manner. A resource may be open for common use naturally. The resource may be available to all naturally because its characteristics prevent it from being owned or controlled by anyone.[64] For example, for most of the earth's history, the oceans and the atmosphere were natural commons.[65] Why? Because, for example, exercising dominion over such resources was beyond the ability of human beings or simply was unnecessary because there was no indication of scarcity.[66]

A resource also may be open for common use as the result of social construction.[67] That is, laws or rules may prohibit

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63. Benkler, *The Political Economy of Commons*, *supra* note 58, at 6.

64. *See* Carol Rose, *Romans, Roads, and Romantic Creators: Traditions of Public Property in the Information Age*, 66 LAW & CONTEMP. PROBS. 89, 93 (2003) [hereinafter Rose, *Romans, Roads, and Romantic Creators*] (discussing the traditional Roman categories of nonexclusive property, one of which, *res communes*, was incapable of exclusive appropriation due to its inherent character).

65. *Id.* ("The usual Roman law examples of *res communes* resources were the oceans and the air mantle, since they were impossible for anyone to own.").

66. *Id.*

67. Paul David and Dominique Foray note that the "activity of diffusing economically relevant knowledge is not itself a natural one." Paul A. David & Dominique Foray, *Information Distribution and the Growth of Economically Valuable Knowledge: A Rationale for Technological Infrastructure Policies*, *in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE, *supra* note 20, at 87, 91. "Rather, it is socially constructed through the creation of appropriate institutions and conventions, such as open science and intellectual property . . . ." *Id.*; *see also id.* at 93–99 (discussing the distribution of scientific and technological knowledge through institutions). The open source and creative commons movements are two prominent examples. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 164–65, 255–56; *see also* J.H. Reichman & Paul F. Uhlir, *A Contractually Reconstructed Research Commons*

ownership or ensure open access, or an open access regime may arise through norms and customs among owners and users. For example, the Internet infrastructure is governed by norms creating an open access regime where end-users can access and use the infrastructure to route data packets without fear of discrimination or exclusion by infrastructure owners.

The general values of the commons management principle are that it maintains openness, does not discriminate among users or uses of the resource, and eliminates the need to obtain approval or a license to use the resource.[68] Generally, managing infrastructure resources in an openly accessible manner eliminates the need to rely on either market actors or the government to "pick winners" downstream.[69] In theory, at least, this catalyzes innovation through the creation of and experimentation with new uses.[70] More generally, it facilitates the generation of positive externalities by permitting downstream production of public goods and nonmarket goods that might be stifled under a more restrictive access regime.[71]

Sustaining both natural commons and socially constructed commons poses numerous challenges, however. Environmental and information resources highlight the most well known and studied dilemmas. Environmental resources suffer from the famous "tragedy of the commons,"[72] a consumption or capacity problem,[73] which is common to many infrastructure resources.

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for Scientific Data in a Highly Protectionist Intellectual Property Environment, 66 LAW & CONTEMP. PROBS. 315, 430–32 (2003).

68. *See, e.g.*, LAWRENCE LESSIG, FREE CULTURE: HOW BIG MEDIA USES TECHNOLOGY AND THE LAW TO LOCK DOWN CULTURE AND CONTROL CREATIVITY (2004) [hereinafter LESSIG, FREE CULTURE]; LESSIG, THE FUTURE OF IDEAS, *supra* note 7; WILLIAM M. LANDES & RICHARD A. POSNER, THE POLITICAL ECONOMY OF INTELLECTUAL PROPERTY LAW 15–16 (2004) [hereinafter LANDES & POSNER, POLITICAL ECONOMY] (acknowledging such benefits with respect to the public domain). Part IV of this Article demonstrates that understanding commons management as applied to specific resources is markedly complex. Some benefits of commons management are easier to ascertain than others, and some potential problems with commons management are not easy to dismiss. *See infra* Part IV.

69. I discuss this point in more detail below. *See infra* Part II.E.

70. *See generally* LESSIG, THE FUTURE OF IDEAS, *supra* note 7.

71. *See infra* Part II.E.

72. *See* Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243, 1244–45 (1968) (advancing the argument that freedom of the commons will result in exhaustion or depletion of natural resources).

73. *See infra* Parts II.B (discussing consumption/capacity issues as they relate to infrastructure resources) and III.A (discussing consumption/capacity issues as they relate to environmental resources).

Information resources suffer from the famous "free-rider" dilemma, a production problem,[74] which is also common to many infrastructure resources. The Internet suffers from both types of problems.[75]

It is interesting how two frequently told stories of uncontrolled consumption—the tragedy of the commons and the free-rider story—came to dominate the policy discourse in the environmental and intellectual property areas and how both stories seem to lead to the conclusion that granting property rights is the best way to manage these resources.[76] Both stories can be translated in game-theoretic terms into a prisoners' dilemma, another good story, although one that does not necessarily point to private property as a solution to the coordination dilemma.[77]

Whichever story one chooses to tell, the underlying economic problems are not insurmountable and should not stand in the way of managing infrastructure in an openly accessible manner. Social institutions reflect a strong commitment to sustaining common access to certain infrastructure resources.[78] As theorized in Part II and illustrated in subsequent Parts, society values common access to infrastructure resources because these resources are fundamental inputs into productive activities that generate benefits for society as a whole.

74. *See infra* Part II.A (discussing the free-rider problem) and Part III.B (discussing information resources).

75. *See infra* Part IV.

76. *See, e.g.*, OSTROM, *supra* note 56, at 3 (connecting the tragedy of the commons with the prisoners' dilemma); Shubha Ghosh, *Patents and the Regulatory State: Rethinking the Patent Bargain Metaphor After* Eldred, 19 BERKELEY TECH. L.J. 1315, 1332 (2004); *cf.* David Driesen & Shubha Ghosh, *The Functions of Transaction Costs: Rethinking Transaction Cost Minimization in a World of Friction*, 47 ARIZ. L. REV. (forthcoming 2005) (manuscript at 24) (suggesting that the goal of minimizing transaction costs in both private law and public law settings "tend[s] to support private markets and private law, while disfavoring established public law" and challenging the desirability of that goal), *available at* http://ssrn.com/abstract=571005; Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 18) ("[F]ree riding seems to be the flip side of the tragedy of the commons . . . .").

77. *See, e.g.*, Wayne Eastman, *Telling Alternative Stories: Heterodox Version of the Prisoners' Dilemma, the Coase Theorem, and Supply-Demand Equilibrium*, 29 CONN. L. REV. 727, 749–51 (1997); David Luban, *The Social Responsibilities of Lawyers: A Green Perspective*, 63 GEO. WASH. L. REV. 955, 963 (1995); David Crump, *Game Theory, Legislation, and the Multiple Meanings of Equality*, 38 HARV. J. ON LEGIS. 331, 375 (2001).

78. *See infra* Parts III, IV.

II. A DEMAND-SIDE THEORY OF INFRASTRUCTURE

This Part develops a demand-side model of infrastructure that provides a better means for understanding and analyzing societal demand for infrastructure resources. The goal is to better understand how value is created and realized by individuals who obtain access to infrastructure resources. This Part begins by reviewing the traditional economic concepts used in welfare analysis of infrastructure goods and then delves deeper to better understand societal demand for infrastructure resources.

Keep in mind that when discussing demand, I am referring to human desire to realize value (or utility), and when discussing societal demand, I am referring to society's aggregated desires. With respect to infrastructure resources, one must better understand how value is created and realized by human beings, and thus, where demand for infrastructure comes from. Only with such an understanding can one analyze and compare provisional mechanisms (supply systems such as markets, government, community, family, and so on), and institutions aimed at optimizing these mechanisms (laws, norms, subsidies, taxes, and so on). This is because a critical aspect of comparative analysis concerns the relative effectiveness of these mechanisms to generate, communicate, process, and respond to demand signals.

Analysts often classify infrastructure resources as public goods,[79] network goods,[80] natural monopolies,[81] or some combi-

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79. *See* Button, *supra* note 19, at 151–55. The public good label does not always fit traditional infrastructure resources well. On one hand, telecommunications networks and courthouses, for example, are subject to congestion; they are not always nonrivalrously consumed. On the other hand, the cost of excluding users of these resources is not always high. *Cf. id.* at 151 (making the same point with respect to transportation and communications infrastructures); *see also infra* Part II.A (discussing the characteristics of public goods).

80. *See infra* Part II.D (discussing network effects).

81. Many traditional infrastructure resources have been analyzed by economists as so-called natural monopolies. *See* VISCUSI ET AL., *supra* note 21, at chs. 11–15. Generally speaking, industries where suppliers of a good or service face a decreasing cost pricing problem are considered natural monopolies; it is efficient to have a single producer supply the good. *Id.* at 323, 351; *see also* Richard A. Posner, *Natural Monopoly and Its Regulation*, 21 STAN. L. REV. 548, 548 (1969) (offering a similar definition of a natural monopoly). Notably, the single producer need not be a for-profit actor; the government or a non-profit entity may serve this function. VISCUSI ET AL., *supra* note 21, at ch. 14. There are a host of regulated monopolies in the United States that provide essential infrastructure. *See* Posner, *supra*, at 549.

In many respects, the natural monopoly problem is a supply-side issue concerning cost recovery, efficient pricing structures, entry management, and nation thereof. Analysts use these classifications to justify government intervention, and proceed to analyze regulatory options.[82] In other words, it is generally accepted that the market will fail in one way or another to efficiently provide society with infrastructure and that there is some role for government intervention.[83] In some cases, the government may supplant the market by supplying the resource directly or contracting directly with providers on behalf of its citizens.[84] In other cases, the government may attempt to correct the market failure through institutions, such as intellectual property and tax incentives, and continue to rely on private actors to assess demand for a resource and supply it to the public.[85] The question then becomes one of comparative institutional analysis: how should the government modify or regulate the market? Many of the debates in this area focus on the degree and form of government intervention into the market.[86] Operating on the premise that markets are the best mechanism to generate and process demand information (e.g., the quantity and quality of infrastructure access that society desires),[87] the analysis of cor-

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consumer protection from monopoly-inflated prices. *See* RICHARD A. POSNER, AN ECONOMIC ANALYSIS OF LAW 363 (6th ed. 2003). There may be some interesting demand-side issues as well. In particular, natural monopoly classification usually depends on both supply and demand information. VISCUSI ET AL., *supra* note 21, at 475–82. We must determine the "socially optimal industry output" before we can determine whether a single supplier would minimize cost and be the most efficient option. *Id.* at 323. To the extent that we are considering an industry that supplies public and social infrastructure, the demand curve may shift such that the socially optimal output increases. According to Viscusi, Vernon, and Harrington, such a shift could lead to declassification as a natural monopoly and reclassification as a potentially competitive industry. *Id.* at 352–53, 440–47. For the remainder of this Article, I put aside natural monopoly theory as it is not especially relevant to the demand-side analysis of infrastructure undertaken here.

82. Examples of these analyses are plentiful. *See, e.g.*, INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT, *supra* note 19.

83. *See id.*

84. *See* VISCUSI ET AL., *supra* note 21, at ch. 14 (discussing public enterprise); *see also* LEVY, *supra* note 22, at 16–17 (discussing procurement and government contracting for infrastructure); Frischmann, *Innovation and Institutions*, *supra* note 33, at 386–87 (same).

85. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 382–85.

86. *See, e.g.*, David F. Batten, *Introduction* to INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT, *supra* note 19, at 1, 10 (arguing that, in an era of increasing privatization, the role of government intervention is at the heart of many infrastructure debates).

87. This may be an overstatement. In regulated markets, particularly those involving so-called natural monopolies, regulated entities must make

rective institutions tends to focus on the supply-side problems noted earlier.[88] Yet the underlying premise does not hold true for all resources. Specifically, markets are not necessarily better than the government or other alternative, nonmarket mechanisms[89] at processing information about or meeting the demands of our complex society for infrastructure.[90]

The remainder of this Part is structured as follows: Section A explores the key economic characteristics necessary to appreciate the demand-side analysis of infrastructure. Section B develops a general definition of infrastructure comprised of three demand-side criteria common to traditional and nontraditional infrastructure resources. Building upon this general definition, section C develops an infrastructure typology to distinguish between commercial, public, and social infrastructure based on the nature of the productive activities facilitated by an infra-

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decisions about how to invest in building the infrastructure resources necessary to service consumers. *See* VISCUSI ET AL., *supra* note 21, at 370–71. Regulators, then, are often involved in verifying that expenditures are justified by demand. In other industries, government contracts with private entities to build infrastructure to meet community demands. *Id.* at 453–74. For the most part, demand assessments for partially (non)rival resources focus on the amount of capacity needed to meet the expected number of users over the lifetime of the project based on estimated use patterns and growth projections.

88. *See supra* notes 43–46 and accompanying text (listing the three major types of supply-side problems).

89. *See, e.g.*, Benkler, *Coase's Penguin*, *supra* note 14, at 381; Benkler, *Freedom in the Commons*, *supra* note 13, at 1247; *cf.* David R. Johnson et al., *The Accountable Internet: Peer Production of Internet Governance*, 9 VA. J.L. & TECH. 9 (2004) (arguing that "peer production of governance" may be the best way to manage the Internet), *available at* http://www.vjolt.net.

90. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 387; *see also* Benkler, *Coase's Penguin*, *supra* note 14, at 406–07; Cohen, *Perfect Curve*, *supra* note 47, at 1809–14. Consider also Cornes and Sandler's comments on the theory of externalities:

> Economists have been criticized, with some justification, for a tendency to forget that institutions other than markets exist and play important roles in allocating resources. [In the context of externalities,] [p]erhaps the absence of a market reflects the availability of some other institutional structure that, in the light of all the frictions and costs of coordination and information gathering, does a good job. Consider the humble traffic light. It does a remarkable job of coordinating motorists' actions at busy intersections. True, there are times when a motorist who is not in a great hurry is allowed to pass straight through, while another, in danger of missing a vital meeting, and hence with a higher marginal cost associated with waiting, fumes and frets at the red light. However, given the current state of technology, it is difficult to imagine how a more efficient method of coordination could be achieved through more-market-oriented devices.

CORNES & SANDLER, *supra* note 31, at 66.

structure resource and the potential for these activities to generate positive externalities. Section D then compares infrastructure and network effects. Critically, both types of economic effects have the potential to generate demand-side externalities, but the externalities attributable to network effects are more likely to be internalized by network providers than the externalities that are attributable to infrastructure effects. Section E evaluates the economic arguments for managing different types of infrastructure resources in an openly accessible manner. Finally, section F addresses how price discrimination affects the demand-side concerns raised in this Article.

A. NONRIVAL AND PARTIALLY (NON)RIVAL GOODS

This section explains why nonrivalry or partial (non)rivalry is a critical characteristic of infrastructure. In short, this characteristic describes the "sharable" nature of infrastructure resources. Infrastructures are sharable in the sense that the resources can be accessed and used by multiple users at the same time. Infrastructure resources vary in their capacity to accommodate multiple users, and this variance in capacity differentiates nonrival (infinite capacity) resources from partially (non)rival (finite but renewable capacity) resources.

Nonrivalry is a key economic concept that one must appreciate when analyzing social welfare from a utilitarian perspective. Synonymous with indivisibility of benefits, nonrivalry describes the situation "when a unit of [a] good can be consumed by one individual without detracting, in the slightest, from the consumption opportunities still available to others from that same unit."[91] For economists, "consumption" simply refers to the realization of benefits by virtue of one's access to the good.

Analysts frequently classify resources based on the degree to which the resource is (non)rival and (non)excludable.[92] Table 1 below presents these classifications. As economists recognize, this classification scheme oversimplifies the true nature of resources. Both rivalrousness and excludability are matters of degree, and these two characteristics often comprise only a piece of the economic puzzle, a point brought into relief by this Article.[93]

91. CORNES & SANDLER, *supra* note 31, at 8.

92. *See id.* at 9.

93. Ultimately, the classification scheme is stretched in different directions when we focus on specific goods. "What matters, however, is the struc-

Table 1: Classification of Resources Based on Rivalrousness of Consumption and Excludability

		EXCLUDABILITY	
		Nonexcludable	**Excludable**
RIVALROUSNESS OF CONSUMPTION	**Nonrival**	"Pure" public goods	Toll goods
	Rival	Common pool resources	"Pure" private goods

It is easy to see how excludability varies by degree. When economists talk about excludability, they refer to the costs of exclusion; that is, how costly it will be for one person to prevent another from consuming the resource.[94] Consider, for example, ideas and apples. It is very difficult to prevent someone else from consuming an idea, and the cost of doing so depends on both context and technology.[95] If I originate an idea, I can prevent others from deriving its benefits if I keep the idea secret. This may involve some internal cost, in terms of precautions I must take to keep the idea secret and perhaps in terms of foregone opportunities to utilize the idea. I will face significantly higher costs if the idea is not my secret, and others may share the idea. Ideas are slippery; it is difficult to maintain exclusive possession of them. In contrast, it is relatively cheap to maintain exclusive possession of an apple and thereby prevent another person from consuming it.

Excludability is relevant to a supply-side analysis of whether markets will work efficiently. Low cost exclusion is one key to a well-functioning market. If one can cheaply exclude others from consuming a resource, one can demand payment as

ture of incentives and the efficiency and distributional implications of the various feasible structures." *Id.* at 10. Shubha Ghosh critiques this classification scheme because it is insufficient in identifying government functions and may be misleading in its prescriptions. *See* Ghosh, *supra* note 42, at 402–06; *see also* OSTROM, *supra* note 56, at 8–15 (critiquing the taxonomical approach for similar reasons); *cf.* Hess & Ostrom, *supra* note 57, at 118–21 (suggesting that scholars sometimes conflate resource classification with property right issues).

94. CORNES & SANDLER, *supra* note 31, at 4, 8–10.

95. For example, the inventions of barbed wire and digital rights management technology greatly reduced the costs of exclusion for land and digital content, respectively. *See* BOLLIER, *supra* note 10, at 27–30, 57.

a condition for access. If one cannot cheaply exclude others from consuming a resource, then the market may fail to satisfy consumer demand for the resource because suppliers will not be able to recoup their costs from consumers. Simply put, a producer of a good must exclude you from consuming the good it has produced if it wishes to charge you for access and consumption. Further, a producer of a good needs to be able to charge you for access if it wishes to recover its costs. If the costs of exclusion are high, then producers must either absorb these additional costs and charge higher fees, or run the risk that consumers will "free ride" (i.e., consume the good without paying). Either route may lead to market failure. Thus, *if* market provision of a resource is desirable[96] but the costs of exclusion are too high, *then* government intervention to fix the market may be appropriate. There are various institutional fixes to this form of market failure.[97]

96. It is a mistake to presume, as many do, that the market mechanism is always the superior mechanism for satisfying social demand for a resource. *See* CORNES & SANDLER, *supra* note 31, at 66; Benkler, *Coase's Penguin*, *supra* note 14, at 406; Cohen, *Perfect Curve*, *supra* note 47, at 1809–14; Moshe Justman & Morris Teubal, *Technological Infrastructure Policy (TIP): Creating Capabilities and Building Markets*, *in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE, *supra* note 20, at 51–52; Nelson, *supra* note 42, at 542–48; *see also supra* note 90. Such a presumption may make sense for certain types of resources, such as private goods, but may be inapposite when applied to public goods. *See* Frischmann, *Internet Infrastructure*, *supra* note 42, at 44 n.138; *see also* CORNES & SANDLER, *supra* note 31, at 66. For public goods and impure public goods, it may be the case that the market mechanism will assess and satisfy social demand more efficiently than the government or alternative mechanisms, *see id.*, but we should not adopt a presumption in favor of the market. The case must be made for each specific resource—or, at the very least—for each category of resource, as I am doing in this Article. *Cf.* Justman & Teubal, *supra*, at 51–52 (implying that this approach is proper). To be clear, I do believe that the market mechanism will be the preferred method of measuring demand for *some* pure and impure public goods. *See* discussion *infra* Parts II.B, II.D.

97. For a discussion of "exclusionary market failure" and intellectual property as a corrective institution for this particular type of market failure, see Frischmann, *Innovation and Institutions*, *supra* note 33, at 359–60, 363–64, 374, 376–82. *See also* James Boyle, *The Second Enclosure Movement and the Construction of the Public Domain*, 66 LAW & CONTEMP. PROBS. 33, 41–42 (2003) [hereinafter Boyle, *Second Enclosure Movement*] (describing the standard argument); Cohen, Lochner *in Cyberspace*, *supra* note 47, at 471 ("By guaranteeing authors certain exclusive rights in their creative products, copyright seeks to furnish authors and publishers, respectively, with incentives to invest the effort necessary to create works and distribute them to the public."); Hess & Ostrom, *supra* note 57, at 119 ("[I]t is very costly to exclude individuals from using the flow of benefits either through physical barriers or legal instruments."); Benkler, Core Common Infrastructure, *supra* note 12, at 3 (not-

Rivalrousness of consumption ("rivalry") is a function of capacity[98] and the degree to which one person's consumption of a resource affects the potential of the resource to meet the demands of others.[99] At the extremes, we can think of purely rival goods, such as apples, and purely nonrival goods, such as ideas. One person's consumption of an apple significantly affects the availability of the apple for anyone else; apples are depleted when consumed. Putting aside transaction costs and distributional issues, it is widely accepted that social welfare is maximized when a rivalrous good is consumed by the person who values it the most[100] and that the market mechanism is gener-

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ing that in the past decade, "American communications and information policy makers" have relied exclusively on "private provision of public goods"). Even if intellectual property is the preferred institutional option for correcting exclusionary market failure, there is a significant debate as to how intellectual property systems might be optimized. *See, e.g.*, Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575 (2003); Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J. ECON. PERSP. 29, 40 (1991) [hereinafter Scotchmer, *Standing on the Shoulders of Giants*]; Christopher S. Yoo, *Copyright and Product Differentiation*, 79 N.Y.U. L. REV. 212 (2004).

98. Capacity is a technological and economic variable that, depending on the context in which it is used, may describe the data-processing ability of a computer system, the data-storage ability of a computer system, the information-carrying ability of telecommunications facilities, or the ability of a lake to process waste. *See, e.g.*, ACADEMIC PRESS DICTIONARY OF SCIENCE AND TECHNOLOGY 353 (Christopher Morris ed., 1992) (defining capacity within the field of computer technology as "the maximum rate at which a computer system can process work," or "the total amount of data that a computer memory component can store"); NEWTON'S TELECOM DICTIONARY 149 (16th ed. 2000) (explaining the different capacity measurements for various telecommunications facilities, such as data lines, switches, and coaxial cables). *See generally* MERRIAM WEBSTER'S COLLEGIATE DICTIONARY 168 (10th ed. 2001) (defining capacity as "the potential or suitability for holding, storing, or accommodating," or "the facility or power to produce, perform, or deploy").

99. Critically, (non)rivalrousness of consumption measures the degree to which one user's consumption of a resource directly affects another user's present consumption possibilities and *not* how production costs are distributed among users. Nonetheless, it is important to remember that congestion costs and production costs may trade off against each other in a cost-benefit analysis. For example, one experiences this trade-off when analyzing whether to invest in technologies which mitigate congestion or increase capacity. *See* discussion *infra* Part II.B.

100. *See* Karl Manheim & Lawrence B. Solum, *An Economic Analysis of Domain Name Policy*, 25 HASTINGS COMM. & ENT. L.J. 359, 403–04 (2003) (discussing Pareto-efficient transactions for private goods); *see also* Harold Demsetz, *The Private Production of Public Goods*, 13 J.L. & ECON. 293, 295 (1970) (explaining that "rationing of [an existing] inventory [of private goods] by market price minimizes the loss in value due to others being excluded from consumption . . . by allocating the inventory to those who find it most valu-

ally the most efficient means for rationing such goods and for allocating resources needed to produce such goods.[101] Thus, producers of apples are given exclusive control over the apples they produce through basic property rights, and those producers are then able to transfer their apples to consumers willing to pay for access.

By contrast, consumption of an idea by one person does not affect the availability of the idea for any one else; an idea is not depleted in quantity or quality when consumed, regardless of the number of persons consuming it. An idea only needs to be created once to satisfy consumer demand while an apple must be produced for each consumer. Essentially, this means that the marginal costs of allowing an additional person to use an idea are zero.[102] Most economists accept that it is efficient to maximize access to, and consequently consumption of, an *existing* nonrival good because generally there is only an upside; additional private benefits come at no additional cost. Ideas, like other nonrival goods, have infinite capacity.

Economists also find that a static, ex post perspective on existing resources is an incomplete perspective. One must adopt a dynamic perspective and consider how nonrival goods are produced and made available to society. From a dynamic perspective, nonrival, nonexcludable goods present a well-known supply-side problem: The inability to cheaply identify and exclude nonpaying users (sometimes called, free riders)[103] coupled with high fixed costs of initial production and low marginal costs of reproduction presents a risk to investors, which

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able").

101. *See* Demsetz, *The Private Production of Public Goods*, *supra* note 100, at 295–96. As Demsetz puts it, "[t]he market price of private goods serves efficiently both the function of rationing the existing inventory and rationing resources into replenishment of the inventory." *Id.*; *see* Spulber & Yoo, *supra* note 43, at 895–98.

102. Note that I have been careful to focus solely on the accessibility rule. I intentionally have excluded distribution or transmission costs from my analysis, which may vary considerably by resource type. *See, e.g.*, Yoo, *Copyright and Product Differentiation*, *supra* note 97, at 231–32 (explaining that marginal costs of making and transmitting copies of a copyrighted work vary on a spectrum depending on, among other things, "the extent to which the copyrighted material must be combined with physical inputs" and whether "every copy of the creative work must be fixed into a physical form").

103. On the free-rider label, see Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 22).

may lead to undersupply by markets.[104] Christopher Yoo explains how this occurs in the context of copyrighted works:

> If authors are to break even, the per-copy price they charge for a work must cover both a portion of the fixed costs needed to produce the work in the first place (often called "first-copy costs") as well as the incremental cost of making the particular copy sold (which economists call "marginal cost"). Allowing third parties to copy freely would allow those third parties to underprice original authors, because the prices charged by those third parties would need only to cover the costs of producing an additional copy without having to include any surplus to defray the first-copy costs incurred by the authors. This would deprive authors of any reasonable prospect of recovering their fixed-cost investments and would thus leave rational authors with no economic incentive to invest in the production of creative works.[105]

Taken together, these two perspectives—static and dynamic efficiency—yield a complicated economic puzzle in terms of maximizing social welfare. As a policy matter, it *may* be necessary to strike a balance between opening access to reap static efficiency gains and restricting access to reap dynamic efficiency gains. Whether this is necessary depends on the resource, the costs and benefits of doing so, and the alternatives available.

At times, nonrivalry seems inextricably linked to nonexcludability[106] and the associated risk of free riding.[107] In a

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104. Basically, high fixed costs of production and low or decreasing marginal costs together mean that average costs will be decreasing. Essentially, the fixed costs of production can be spread over a larger number of consumers. Such a cost structure makes pricing difficult but possible, as discussed above with respect to natural monopolies. *See supra* note 81. High costs of exclusion may lead to exclusionary market failure for the reasons discussed in the text above. However, it is critical to keep in mind that high exclusion costs do not inevitably lead to market failure, as the existence of visible private flower beds should remind us. *See infra* Part II.C.2 (discussing private flower bed example); Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 21–22).

105. Yoo, *Copyright and Product Differentiation*, *supra* note 97, at 214–15. *See generally* LANDES & POSNER, POLITICAL ECONOMY, *supra* note 68, at 22–23; Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY: ECONOMIC AND SOCIAL FACTORS 609, 614–16 (Nat'l Bureau Econ. Research 1962); Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989 (1997) [hereinafter Lemley, *The Economics of Improvement*]; Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 22).

106. In a seminal article, Demsetz made a similar observation, arguing that "[t]here is nothing in the public good concept that disallows the ability to exclude." Demsetz, *The Private Production of Public Goods*, *supra* note 100, at 295. Demsetz applied the label "public goods" to nonrivalrously consumed goods, and viewed nonrivalrously consumed, nonexcludable goods as a subset

sense, nonrivalry opens the door to free riding, and in some cases makes it likely—if not inevitable—because nonrival goods can be consumed by many persons simultaneously and jointly.[108] Producers of nonrival goods seeking to maximize their returns face the risk that nonpaying consumers may obtain access to the goods (e.g., from competitors that need not bear the fixed cost of production and thus may sell the good at marginal cost), but this risk is really a function of excludability, not nonrivalry.[109] More importantly, not all nonrival goods are produced by entities seeking to maximize profits or recoup their costs of production (consider, for example, national security), nor are all such goods even produced (consider, for example, sunshine).

Yet possible free riding drives analysts to focus on supply-side considerations, and more specifically, to correct market-driven supply problems by designing property-based institutions to lessen the costs of exclusion and minimize free riding.[110] As I have argued elsewhere, nonexcludability is not a necessary condition for market failure; markets may fail for many other reasons. Nor, however, does exclusion fix all market failures.[111] In fact, exclusion may aggravate other failures of the market. Even if an owner can exclude users from a nonrival resource and therefore meter use by charging a fee, dynamic inefficiencies still may abound.[112] Simply put, property rights and other institutions that lessen the costs of exclusion

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of "public goods" which he referred to as "collective goods." *Id.*

107. This relates to an earlier point: economists tend to focus on the public good classification initially and then swiftly shift to the supply-side analysis of institutions designed to fix exclusionary market failure without carefully considering the potential benefits of nonrivalrous consumption. *See supra* notes 40–46 and accompanying text.

108. As Mark Lemley notes with respect to intellectual property, "[W]e should not therefore be particularly worried about free riding in information goods. It is not that free riding won't occur with information goods; to the contrary, it is ubiquitous." Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 26).

109. Consider excludable goods, such as a telecommunications network, that exhibit similar cost structures (high fixed costs coupled with low marginal costs, and thus decreasing average costs). Such goods do not encounter the free-riding problem.

110. *See* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 3–17).

111. *See* Frischmann, *Innovation and Institutions*, *supra* note 33; Frischmann, *Internet Infrastructure*, *supra* note 42.

112. *See, e.g.*, Cohen, *Perfect Curve*, *supra* note 47, at 1807–09; Lemley, *The Economics of Improvement*, *supra* note 105, at 1056–58.

and facilitate market-driven provision of nonrival goods are no panacea. As two well-respected economists, Richard Cornes and Todd Sandler, observed:

> Exclusion . . . can strengthen the motives for production of a public good and make possible the operation of a market. Given the efficiency problems associated with pure public goods, it is interesting to consider whether or not the possibility of exclusion is sufficient to restore the presumption that market provision is efficient. . . .
>
> . . . A number of writers have investigated the implications of price excludability under various assumptions regarding market structure and the amount of information about demand possessed by the supplier. There are no clear conclusions, except that Pareto efficiency is not guaranteed by the possibility of exclusion. Excludability alone cannot reinstate the presumptive efficiency of decentralized market provision, and most writers . . . have argued for a presumption of underprovision even when exclusion is possible.[113]

Critically, focusing on free-riding and market-driven supply obscures the economic meaning and importance of nonrivalry.[114] Developing a more sophisticated understanding of what nonrivalry facilitates is crucial to providing a more robust economic argument for commons management.[115] Nonrivalry opens the door to much more than free-riding.

When analyzing nonrival and partially (non)rival resources, it is important to distinguish between consumption goods and intermediate goods (inputs).[116] Consumption goods

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113. CORNES & SANDLER, *supra* note 31, at 56–57 (citation omitted).

114. The "enclosure movement" has developed considerable momentum and theoretical leverage based on the free-riding concept. *See* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 12–17). William Landes and Richard Posner provide an interesting explanation as to growth of intellectual property protection since 1976. They suggest that the free-market ideology behind the deregulation movement also pushed towards increasing the strength of intellectual property rights. *See* LANDES & POSNER, POLITICAL ECONOMY, *supra* note 68, at 22–23. The problem, they argue, is that "[i]ntellectual property was already 'deregulated' in favor of a property rights system, and the danger that the system would be extended beyond the optimal point was as great as the danger that it would be undone by a continuing decline in the cost (especially the quality-adjusted cost) of copying." *Id.* at 23.

115. *See* David & Foray, *supra* note 67, at 87–88 (providing a strong economic argument for open access and knowledge distribution that focuses on "optimal utilization of a nonrival good" and the dominance of positive externalities derived from learning and productive use of knowledge); *see also* Benkler, *Coase's Penguin*, *supra* note 14, at 404–05, 438–39; Boyle, *Second Enclosure Movement*, *supra* note 97, at 44–46 (discussing distributed creativity).

116. *See* Cohen, *Perfect Curve*, *supra* note 47, at 1803–04 (explaining that the traditional economic analysis of the supply and demand curves for copyrighted information views the consumer surplus as a benefit derived from con-

are consumed directly by the user to generate private benefits. Nonrival consumption goods are subject to the economic considerations set forth above. From a static efficiency perspective, maximizing access for consumption maximizes social welfare, but from a dynamic efficiency perspective, such a policy could lead to market failure (if the good is supplied by the market) because of free-riding concerns.[117]

In contrast, intermediate goods are used as inputs to produce other goods. Nonrival intermediate goods (nonrival inputs) may be used by multiple users as an input to produce other goods (outputs).[118] This is a door opened by nonrivalry worth exploring more carefully.[119]

Generally, demand for nonrival inputs depends on the nature of the outputs. As discussed in more detail in the next section, however, evaluating demand may be difficult where the outputs are public goods and nonmarket goods. Yet the social benefits derived from widespread access to a nonrival input used to produce such goods may be quite large.[120] Thus, a de-

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sumption and not productive use); Lemley, *The Economics of Improvement*, *supra* note 105, at 1056–58.

117. Note that maximizing access does not mean free provision, nor does it mean force-feeding. Even from a static perspective, consumers presumably must bear any distribution costs, and those consumers for whom the marginal benefits of consumption are less than the marginal costs of distribution may decline to access the good. *See* Spulber & Yoo, *supra* note 43, at 896.

118. Throughout this Article, I have used input-output terminology to describe resource use in production processes. There are other ways to describe these relationships. One alternative refers to generic or basic inputs as platforms. *See, e.g.*, sources cited *infra* note 143. Another refers to the relationships in terms of layers. *See, e.g.*, sources cited *infra* note 335. As I am spanning a number of disciplines, there is bound to be some confusion with respect to terminology, which I can only hope to minimize.

119. The cumulative nature of information production is well recognized in the literature and is the subject of extensive academic study. *See, e.g.*, TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE, *supra* note 20, at 8 n.2 ("Cumulative forms of knowledge are those in which today's advances lay the basis for tomorrow's, which in turn lay the basis for the next round. The integrative aspect of the production of knowledge means that new knowledge is selectively applied and integrated into existing systems to create new systems."); Frischmann, *Innovation and Institutions*, *supra* note 33; Robert P. Merges & Richard R. Nelson, *On Limiting or Encouraging Rivalry in Technical Progress: The Effect of Patent Scope Decisions*, 25 J. ECON. BEHAV. & ORG. 1 (1994); Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839 (1990); Scotchmer, *Standing on the Shoulders of Giants*, *supra* note 97; Benkler, The Commons as a Neglected Factor of Information Policy, *supra* note 5.

120. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 87 (arguing that a resource should be managed in an openly accessible manner when the re-

mand-side emphasis is critical to valuing nonrival inputs, both in terms of measurement (i.e., the actual value of the resource) and in terms of understanding *how* the resource creates social value. These are related tasks, but one only begins to grasp the true social value of infrastructure resources when one looks to the downstream uses and applications. At a minimum, policy decisions aimed at striking a balance between opening access to reap static efficiency gains and restricting access to reap dynamic efficiency gains ought to explicitly take these issues into account.

So far, I have discussed extremes, describing purely nonrival goods such as ideas and purely rival goods such as apples. It is important, however, to understand that there are a host of resources in between these extremes, generally referred to as impure public goods.[121] An important subset of these in-between resources includes *partially (non)rival goods.*

Partially (non)rival goods are durable goods that have finite, renewable, and sharable capacity. Whether these resources are consumed nonrivalrously or rivalrously often depends on other conditions, such as how the resource is managed, the number of users, and the available capacity. I refer to these resources as partially (non)rival goods because they can be managed in a way that avoids rivalrous consumption. To be clear, this concept focuses on how one user's consumption directly affects another user's, not on how production costs are distributed among users. Consider a resource with finite, sharable capacity, such as a lake or computer network. Up to a point, the marginal costs of allowing an additional user to access and use the resource are zero; beyond that point, the marginal costs become positive and increase with each additional user.[122] This assumed structure does not perfectly fit all resources; deviations will vary across resources. An important

source is "'most valuable when used by indefinite and unlimited numbers of persons'" (quoting Rose, *The Comedy of the Commons*, *supra* note 26, at 744)); Benkler, *Coase's Penguin*, *supra* note 14, at 369 (discussing the benefits of peer-production of information).

121. CORNES & SANDLER, *supra* note 31, at 9; *cf.* Benkler, The Commons as a Neglected Factor of Information Policy, *supra* note 5, at 13 (noting that market-based production of a nonrival input will lead to a different output mix than commons-based production).

122. *See, e.g.*, CORNES & SANDLER, *supra* note 31, at 272–77 (describing congestible resources); Abraham Bell & Gideon Parchomovsky, *Of Property and Antiproperty*, 102 MICH. L. REV. 1, 13 (2003) (observing that parks are impure public goods that "admit of nonrivalrous uses only to a certain point").

deviation occurs where, in addition to multiple users, there are multiple uses of the resource for which compatibility, potential rivalry in consumption, and potential benefits vary.[123] Depending upon the number and types of potential uses, the degree to which they compete with each other, and the value each has the potential to generate, we might wish to avoid reaching the congestion point.

From the demand side, the absence of resource depletion and the possibility of avoiding congestion while still allowing multiple users (uses) is what makes the resource partially (non)rivalrous. I recognize that this terminology is a bit unusual in the sense that most economists would not characterize precongestion consumption as nonrivalrous. Instead, they would view consumption as depletion of the fixed capacity available and thus as rivalrous. As I see it, temporary depletion of renewable capacity that does not cause any congestion externalities is not strictly rivalrous.[124]

There is a close connection between partially (non)rival resources and "club goods."[125] Cornes and Sandler define club goods as a subclass of impure public goods that are partially rival, excludable goods.[126] Cornes and Sandler assume that exclusion is practiced for club goods and analyze decisions as to club membership, the provision quantity of a shared resource, and congestion management.[127] Most, if not all, club goods are partially (non)rival in the sense that they can be managed in a fashion that eliminates congestion (rivalrousness in consumption) by keeping membership size small.[128] As Cornes and Sandler remarked, "Congestion is not something that must be completely eliminated; rather an optimal level of congestion must be found."[129] As discussed below, figuring out the optimal level of congestion is a critical question for infrastructure. For purposes of this Article, I employ the term "partially (non)rival

123. Both lakes and the Internet exhibit variance in these dimensions. *See* discussion *infra* Parts III.A, IV.

124. *Cf.* Benkler, *Overcoming Agoraphobia*, *supra* note 13, *passim* (discussing sharable resources with finite but perfectly renewable capacity); Benkler, The Commons as a Neglected Factor of Information Policy, *supra* note 5, at 21 (same).

125. *See* CORNES & SANDLER, *supra* note 31, at 349–51; James M. Buchanan, *An Economic Theory of Clubs*, 32 ECONOMICA 1 (1965).

126. CORNES & SANDLER, *supra* note 31, at 9, 349–50.

127. *See id.* at 347–69.

128. *See id.* at 348–49.

129. *Id.* at 524–25.

resources" rather than impure public goods or club goods for two reasons: (1) to emphasize that the degree of (non)rivalry of consumption is variable and often manageable; and (2) to emphasize that the means for managing congestion is also variable, as I discuss below.[130] Table 2 illustrates the categorization of goods as the degree of rivalry varies.

Table 2: Classification of Goods Based on Degree of Rivalrousness

		TYPE OF GOOD
RIVALROUSNESS OF CONSUMPTION	**Nonrival**	Pure public good (idea)
	Partially (non)rival	Impure public good (lake, road, the Internet)
	Rival	Private good (apple)

Many partially (non)rival resources are *sometimes* nonrivalrously consumed and *sometimes* rivalrously consumed, depending upon the number of users and available capacity at a particular time.[131] Highways, in real space and cyberspace, offer excellent illustrations.[132] During off-peak hours, consumption of these resources is often nonrivalrous. At these times, users do not impose costs on other users and the marginal cost of allowing an additional person to use the resource is zero. At some point, however, nonrivalrous consumption turns rivalrous and congestion problems arise. Congestion on the highway or on the Internet is a function of variable demand imposed on a

130. We will revisit excludability and restrictions on membership size below. *See infra* Part III.A (discussing targeted regulation of certain sets of users/uses of a resource in order to avoid congestion and sustain nonrival consumption by other sets of users/uses).

131. *See, e.g.*, Frischmann, *Internet Infrastructure*, *supra* note 42, at 25–34 (modeling the Internet interconnection infrastructure as a sometimes rivalrous good).

132. The "information superhighway" metaphor has been critiqued by many, and rightly so, in my opinion, to the extent that the metaphor is used as the exclusive lens for elucidating the relevant "facts of the Internet" in a legal dispute. *See* Brett M. Frischmann, *The Prospect of Reconciling Internet and Cyberspace*, 35 LOY. U. CHI. L.J. 205 (2003). Nonetheless, the metaphor is a useful way of thinking about the physical infrastructure of the Internet (i.e., the interconnected networks and nodes that transport information to and from computers at the ends) from an economic perspective. *See id.*

system with finite capacity. As a general matter, congestion dissipates over time and the capacity of the resource is renewed. Thus, it is not permanently depleted, unless the system is overwhelmed and crashes.[133]

Like a door that may be closed, opened, or left partially open, partially (non)rival resources present choices.[134] Opening the door to take advantage fully of nonrivalry may require investments in capacity expansion and/or access restrictions tailored to control congestion. It is important to realize that not all partially (non)rival goods are amenable to capacity expansion. Highways or telecommunications systems can be expanded; others, like some environmental resources that act as a sink for pollutants, cannot.

For expandable infrastructure resources, the costs of expansion (e.g., adding more lanes to a highway or more fiber optic cables to the Internet network) must be weighed against the costs of congestion (e.g., slowing down traffic) and/or the costs of regulating use in a manner that prevents congestion (e.g., prohibiting certain traffic during peak load times).[135] Instead of building capacity sufficient to handle all users and uses at all times, we might prefer to regulate certain types of uses. For example, imagine that if we keep a certain class of vehicles (big trucks) off the highway during rush hour, we could then keep the highway completely open for all other types of vehicles without suffering any congestion, meaning the marginal cost of each additional allowable vehicle (non-big-truck) is zero. This type of management scheme imposes costs on the regulated vehicles to avoid congestion costs on the unregulated vehicles. Rather than spreading congestion costs on all users (or perhaps on the entire tax base), displacement costs are placed on a particular class of users. For these resources, we must make the difficult choice between building congestion-free levels of capacity (which may be cost prohibitive), saddling all congestion costs on a particular class of users, or spreading congestion costs among all users.

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133. Some infrastructure resources are more vulnerable to being overwhelmed than others. *See* Robert Wilson, *Architecture of Power Markets*, 70 ECONOMETRICA 1299, 1302 (2002) (discussing technological transmission constraints and vulnerability to "instability, cascading failures, or collapse at great cost").

134. "Closing the door" entails "enclosure" of a resource. *Cf.* Boyle, *Second Enclosure Movement*, *supra* note 97, *passim* (addressing the second enclosure movement).

135. *See infra* Parts III.A, IV (using examples to illustrate trade-offs).

Further, if expansion is desirable, it is necessary to determine who will finance this investment.[136] If, on one hand, capacity expansion is to be financed privately, then private actors may push for private ownership and control over the conditions of access to the resource to ensure that payments can be extracted from users. On the other hand, capacity expansion may be financed publicly, or perhaps through alternative means, which may be worthwhile if open access is socially desirable.

Expansion of capacity is not the only (or even predominant) means of eliminating or controlling rivalrous consumption. Uses can be regulated by the market through pricing,[137] the government by regulation,[138] norms, or even technology that mitigates congestion.[139] Such institutional structures must be evaluated carefully and contextually.

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136. The "lumpiness" of investments in capacity expansion presents a related supply-side issue. As Spulber & Yoo explain:

> Capacity in network industries is notoriously "lumpy" in that it can only be efficiently added in large, discrete quantities. In addition, if the needs of network users are to be met, such capacity must necessarily be added before it is actually needed, a problem that is particularly acute for carriers of last resort who are obligated to provide service to anyone who requests it. The tendency towards excess capacity is exacerbated further by the manner in which excess capacity can enhance network reliability and provide insurance against unforeseeable variability in demand. These qualities make excess capacity a feature that is endemic to all networks. In addition, these courts have fallen into the same trap as computer system managers that have allowed additional users free use of what, at the time, appeared to be excess capacity. That is, this approach overlooks the fact that use of what appears to be excess capacity imposes real costs by hastening the need for additional capacity.

Spulber & Yoo, *supra* note 43, at 913. From a social welfare perspective, it may, at times, be desirable to have excess capacity and "hasten[ ] the need for additional capacity" for public and social infrastructure. *Id.*

137. *See* Benkler, *Overcoming Agoraphobia*, *supra* note 13, at 352. Benkler explains:

> Overuse expressed as congestion will lead to queuing—or higher prices—expressed in time. Queuing, in turn, is the appropriate allocation method whenever the cost of avoiding queuing—increasing capacity or instituting a price system without a queuing component—is higher than the cost of the time lost in the queue.

Id.

138. *See infra* Part III.A (discussing regulation of consumptive uses).

139. "A spectrum commons is possible because spectrum, while rivalrous, is inexhaustible and perfectly renewable, permitting rival uses to be coordinated better with equipment that utilizes these attributes than with institutions developed to overcome more primitive technological conditions." Benkler, The Commons as a Neglected Factor of Information Policy, *supra* note 5, at 21.

To be clear, not all nonrival or partially (non)rival goods are infrastructure, and not all nonrival or partially (non)rival goods should be managed in a manner that takes advantage of nonrivalry. First, to qualify as "infrastructure," a resource must act as an input into the production of a wide variety of outputs.[140] Second, even if a resource can be characterized as infrastructure, whether it should be managed in a manner that takes advantage of nonrivalry (i.e., in an openly accessible manner) will depend on the context and the mix of outputs it generates. The next section addresses these questions.

B. DEFINING INFRASTRUCTURE FROM THE DEMAND SIDE

Infrastructure resources are resources that satisfy the following demand-side criteria:

(1) The resource may be consumed nonrivalrously;

(2) Social demand for the resource is driven primarily by downstream productive activity that requires the resource as an input; and

(3) The resource may be used as an input into a wide range of goods and services, including private goods, public goods, and nonmarket goods.

Traditional infrastructure, such as roadways, telephone networks, and electricity grids, satisfy this definition, as do a wide range of resources not traditionally considered to be infrastructure resources, such as lakes, ideas, and the Internet.

The first criterion captures the consumption attribute of nonrival and partially (non)rival goods, as detailed in the previous section. Simply put, nonrivalry opens the door to widespread shared access and productive use of the resource. For nonrival resources of infinite capacity, the marginal cost of allowing an additional person to access the resource is zero.[141] For partially (non)rival resources of finite capacity, the cost-benefit analysis is more complicated, but the potential for an

140. For purposes of this Article, at least.

141. To be clear, allowing access and providing access are two different concepts. Allowing access simply means not restricting or erecting barriers to access. If marginal distribution costs are greater than zero, which will often be the case, then the person seeking access generally is required to bear these costs, absent a subsidy scheme. I recognize that exclusion may be necessary in some cases to recover such costs and/or the fixed costs of production. Keep in mind, however, that I am focusing on the demand side. The key point is that allowing consumers access to the resource has no impact on the availability of the resource for other consumers.

open door or partially open door must be taken into account when evaluating provisional mechanisms (e.g., market, government, community, family, and individual supply systems), and institutions aimed at optimizing these mechanisms (e.g., laws, norms, subsidies, and taxes).

The second and third criteria focus on the manner in which infrastructure resources create social value. The second criterion emphasizes that infrastructure resources are intermediate goods that create social value when utilized productively downstream and that such use is the primary source of social benefits. In other words, while some infrastructure resources may be consumed directly to produce immediate benefits, most of the value derived from the resources results from productive use rather than consumption.[142] Essentially, infrastructure resources are enabling "platforms" upon which others build.[143]

The third criterion emphasizes both the variance of potential downstream outputs (the *genericness* of the input) and the nature of those outputs (particularly public goods and nonmarket goods).[144] The reason for emphasizing variance and the pro-

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142. For some infrastructure resources, all of the value is derivative. For other infrastructure resources, there is a balance between productive use and consumption. *See, e.g., infra* Part IV (detailing how the Internet falls into the latter category). For purposes of this Article, I am not concerned with drawing a bright line between the two.

143. Jonathan Zittrain has analyzed the importance of open platform technologies and ways to encourage their development. *See* Jonathan Zittrain, The Future of the Internet—And How To Stop It (Jan. 2005) (working paper, on file with author). On platforms, see Shane Greenstein, *The Evolving Structure of the Internet Market, in* UNDERSTANDING THE DIGITAL ECONOMY 151, 154–55 (Erik Brynjolfsson & Brian Kahin eds., 2000) ("A platform is a common arrangement of components and activities, usually unified by a set of technical standards and procedural norms around which users organize their activities. Platforms have a known interface with respect to particular technologies and are usually 'open' in some sense.") (citation omitted) and ANNABELLE GAWER & MICHAEL A. CUSUMANO, PLATFORM LEADERSHIP: HOW INTEL, MICROSOFT AND CISCO DRIVE INDUSTRY INNOVATION 55 (2002), *quoted in* Cooper, *supra* note 27, at 29 (describing platform technologies as "enabling technologies" that "exist to entice other firms to use them to build products that conform to the defined standards and therefore work efficiently with the platform").

144. *See* Justman & Teubal, *supra* note 96, at 21–23 (defining technological infrastructure as "a set of collectively supplied, specific, industry-relevant capabilities, intended for several applications in two or more firms or user organizations"); Gregory Tassey, *Infratechnologies and Economic Growth, in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE, *supra* note 20, at 59, 59–60 (similarly defining technological infrastructure as generic and jointly used inputs); *see also* Justman & Teubal, *supra* note 96, at 24 n.5 (describing genericness as having broad relevance from a demand perspective for multiple users/uses).

duction of public goods and nonmarket goods downstream is that when these criteria are satisfied, the social value created by allowing additional users to access and use the resource may be substantial but extremely difficult to measure.[145] The information problems associated with assessing demand for an infrastructure resource and valuing its social benefits plague both suppliers and consumers of that resource where consumers are using the infrastructure as an input into the production of public goods or nonmarket goods. This is an information problem that is pervasive and not easily solved.[146]

Whether we are talking about transportation systems, the electricity grid, ideas, environmental ecosystems, or Internet infrastructure, the bulk of the social benefits generated by these resources derives from their downstream uses. They create value downstream by serving a wide variety of end-users who rely on access to them. Yet social demand for the infrastructure itself is extremely difficult to measure.

A road system, for example, is not socially beneficial simply because we can drive on it. I may realize direct consumptive benefits when I go cruising with the windows down and my favorite music playing,[147] but the bulk of social benefits attributable to a road system comes from the activities it facilitates at the ends, including, for example, commerce, labor, communications, and recreation.[148] As recognized by the National Research Council, "[i]nfrastructure is a means to other ends, and the effectiveness, efficiency, and reliability of its contribution to these other ends must ultimately be the measure of infrastruc-

145. This may give rise to market failure that is related to, but still different and more complicated than, market failure traditionally associated with public goods. Once we establish the existence of this type of market failure and that pure market provision of these resources is socially undesirable, we must carefully consider the institutional response—whether substitution of an alternative provider or institutional intervention into the market will improve its performance. This institutional analysis must take into account the ways in which infrastructure resources differ from ordinary public goods. *See* Tassey, *supra* note 144, at 67–72 (describing a variety of technology-based market failures).

146. *Cf.* Benkler, *Overcoming Agoraphobia*, *supra* note 13, at 375–88, 390 (discussing information and transaction cost problems "associated with articulating and communicating preferences about the use of communications infrastructure in an imperfect market").

147. *See* Benkler, Core Common Infrastructure, *supra* note 12, at 22 (discussing the benefits of driving on the open road).

148. Rose, *The Comedy of the Commons*, *supra* note 26, at 768–70; *see also* Benkler, Core Common Infrastructure, *supra* note 12, at 22–23.

ture performance."[149] Yet, despite general recognition that social demand for infrastructure is driven by downstream applications, theoretical modeling of this relationship and empirical measurement of value creation downstream appear underdeveloped and incomplete.[150]

From an economic perspective, it makes sense to manage certain infrastructure resources in an openly accessible manner because doing so permits a wide range of downstream producers of private, public, and nonmarket goods to flourish. As Yochai Benkler has noted, "[t]he high variability in value of using both transportation and communications facilities from person to person and time to time have made a commons-based approach to providing the core facilities immensely valuable."[151] The point is not that all infrastructure resources (traditional or nontraditional) should be managed in an openly accessible manner, but rather that, for certain classes of resources, the economic arguments for managing the resources in an openly accessible manner vary in strength and substance. The next section further refines the economic theory by defining three classes of infrastructure resources: commercial, public, and social infrastructure. As a general matter, economic arguments for managing an infrastructure resource in an openly accessible manner vary by type and are stronger for the latter two types.[152] For commercial infrastructure, the arguments are largely grounded in concerns about anticompetitive behavior and/or natural monopolies. For public and social infrastructure, the arguments extend further to encompass information and transaction cost problems that inhibit efficient operation of both markets and targeted government subsidies.

C. AN INFRASTRUCTURE TYPOLOGY

To better understand and evaluate these complex economic relationships, I define three general categories of infrastructure resources, illustrated in table 3, based on the nature of the dis-

149. COMM. ON MEASURING & IMPROVING INFRASTRUCTURE PERFORMANCE, NAT'L RESEARCH COUNCIL, MEASURING AND IMPROVING INFRASTRUCTURE PERFORMANCE 5 (1995).

150. The difficulty in assessing social demand for the infrastructure resource is experienced in traditional infrastructure industries. CORNES & SANDLER, *supra* note 31, at 483–505.

151. Benkler, Core Common Infrastructure, *supra* note 12, at 47–48.

152. *See infra* Part II.D (explaining the various economic arguments for managing each type of infrastructure resource in an openly accessible manner).

tribution of downstream activities: commercial, public, and social infrastructure.

Table 3: Typology of Infrastructure Resources

Type	Definition	Examples
COMMERCIAL INFRASTRUCTURE	Nonrival or partially (non)rival input into the production of a wide variance of private goods	1. Basic manufacturing processes 2. Cable television 3. The Internet 4. Road systems
PUBLIC INFRASTRUCTURE	Nonrival or partially (non)rival input into the production of a wide variance of public goods	1. Basic research 2. Ideas 3. The Internet
SOCIAL INFRASTRUCTURE	Nonrival or partially (non)rival input into the production of a wide variance of nonmarket goods*	1. Lakes 2. The Internet 3. Road systems

* The last subset also includes many traditional infrastructure, such as governance systems and school systems.

These categories are neither exhaustive nor mutually exclusive. Real-world infrastructure resources often fit within more than one of these categories at the same time. For example, as explored in Part IV, the Internet is a combination of all three types of infrastructure. I will refer to such infrastructure resources as "mixed" and to infrastructure resources that fall within only one category as "pure." This schema provides a means for understanding the social value generated by these infrastructure resources and identifying different types of market failures.

1. Commercial Infrastructure

Commercial infrastructure resources are used to produce private goods.[153] Consider the examples listed in table 3. Basic

153. A private good is a rivalrously consumed good, such as an apple. *See supra* Part II.A.

manufacturing processes, such as die casting, milling, and the assembly line process, are nonrival inputs into the production of a wide variety of private manufactured goods. Similarly, basic agricultural processes and food processing techniques are nonrival inputs into the production of a wide variety of private agricultural goods and foodstuffs. Many commercial infrastructure resources are used productively by suppliers purely as a delivery mechanism for manufactured goods, agricultural goods, foodstuffs, and many other commercial products, including digital content. A cable television system, for example, acts as an input into the delivery of copy-protected (or "controlled") digital content purely for consumption by an end-user (e.g., a cable customer). Content providers use the infrastructure to provide a private service to the consumer (delivery of content for consumption) under conditions that render the output rivalrous and excludable. At least in theory, a wide variety of content suppliers can deliver a wide variety of content under such conditions. Similarly, the Internet and road systems are used by a wide range of suppliers to deliver private goods and services.

For pure commercial infrastructure, basic economic theory predicts that: (1) competitive output markets should work well and effectively create demand information for the input,[154] (2)

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154. It may be the case that commercial infrastructure may run into a similar type of demand-side market failure as discussed below with respect to public and social infrastructure. *See infra* Part II.C.2. Consumer surplus is the portion of the value created by outputs that is not captured by output producers. *See* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 19–25). If (1) access is prioritized (e.g., due to capacity constraints) and (2) perfect price discrimination is not effective in the input market, infrastructure suppliers may bias access priority or optimize infrastructure design in favor of output markets that generate the highest levels of appropriable returns, perhaps at the expense of output markets that generate a larger aggregate surplus (consumer surplus plus producer surplus). *See id.* (manuscript at 30–43). I thank Mark Lemley for raising this issue. While interesting, I leave further consideration for future work. Lemley sets forth the issue as follows:

> If there is a chain of markets, each with its own positive externalities, the initial owner may demand a fee for licensing which is less than the aggregate social value across all markets, but greater than the private value users can capture. In this case, market failure will cause us to forego efficient new uses.... In short, granting perfect control privileges initial inventors at the expense of improvers, and may therefore actually reduce the size of positive externalities from invention by discouraging the improvements and new uses which generate those externalities.

Id. (manuscript at 39–40).

market actors (input suppliers) will process this information, and (3) demand will be satisfied efficiently.[155] Simply put, for commercial infrastructure, output producers should fully appropriate the benefits of the outputs (via sales to consumers) and thus accurately manifest demand for the required inputs in upstream markets. Therefore, with respect to demand for commercial infrastructure, the key is maintaining competition in the output markets, where producers are competing to produce and supply private goods to consumers. Competition is the linchpin in this context because the public's consumptive demands can be best assessed and satisfied by competitive markets.

The first two points underlie one of the famous arguments made by Ronald Coase in *The Marginal Cost Controversy*.[156] Coase argued that governments should not subsidize public access to utilities (natural monopolies) with an aim toward keeping prices charged to consumers at marginal cost.[157] Doing so, he argued, would distort the market and disrupt its ability to generate and process individual demand information.[158] I agree with Coase on this point as it pertains to demand for pure commercial infrastructure. As I will discuss below, however, the argument does not apply with equal force to public and social infrastructure. First, social and individual demand for access to infrastructure will diverge to the extent that individuals are unable to appropriate the full value of outputs they generate.[159] Second, managing the infrastructure resource in an openly accessible manner does not preclude market or government provision. It does, however, avoid relying on either the pricing system or the government to assess demand on an *individualized*

155. With respect to the third point, there is significant disagreement among economists about the need for competitive input markets and the need for government intervention into various input markets. The thrust of the arguments made in this debate concern incentives, the presence of natural monopolies, strategic behavior by monopolists (infrastructure providers), and the effectiveness of government intervention. These debates generally focus on supply-side issues without challenging the first two points made above.

156. *See* R.H. Coase, *The Marginal Cost Controversy*, 13 ECONOMICA 169 (1946) [hereinafter Coase, *The Marginal Cost Controversy*]; R.H. Coase, *The Marginal Cost Controversy: Some Further Comments*, 14 ECONOMICA 150 (1947) [hereinafter Coase, *Some Further Comments*].

157. Coase, *The Marginal Cost Controversy*, *supra* note 156, *passim*.

158. *Id.* at 176; *cf.* Buchanan, *supra* note 125 (making a similar demand-side argument with respect to investing in capacity beyond the point of congestion for club goods).

159. *See infra* Part II.C.2.

basis, which is precisely the advantage of a commons management regime. For infrastructure managed in an openly accessible manner, demand is assessed more crudely on a group, community, or societal basis.[160]

Not surprisingly, the topic of open access to commercial infrastructure roots itself in the familiar territory of antitrust, regulated markets, and commons-like management principles of common carrier and essential facilities doctrines.[161] Historically, common carrier obligations were said to arise in markets "affected with the public interest."[162] According to Richard Epstein, government intervention into such markets to ensure public access was justified because of the risk of market dominance and the lack of competition upstream (in the input market).[163]

One of the insights that flows from this infrastructure model is that these regulatory principles are being applied to a subset of a much broader phenomenon. First, there is a wider range of resources that are "affected with the public interest" and that are candidates for similar institutional treatment. Second, the institutional response—common carrier regulation—need not be justified purely on the argument that it is necessary to facilitate competition downstream. When the downstream uses or applications of an infrastructure resource include the production of public goods and nonmarket goods, the case for common carrier regulation may be even stronger. Mark Cooper stated the argument nicely:

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160. *See* Harold Hotelling, *The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates*, 6 ECONOMETRICA 242, 247–48 (1938) (deciding whether demand was sufficient to justify the costs of building a bridge "would be a matter of estimation of vehicular and pedestrian traffic originating and terminating in particular zones, with a comparison of distances by alternative routes in each case, and an evaluation of the savings in each class of movement"), *quoted in* Coase, *The Marginal Cost Controversy*, *supra* note 156, at 175.

161. For a discussion of the history and role of common carrier obligations on infrastructure providers, see Cooper, *supra* note 27, at 3–5. Cooper also argues that these principles should extend to the Internet. *See id.* at 39–45.

162. *See* RICHARD A. EPSTEIN, PRINCIPLES FOR A FREE SOCIETY: RECONCILING INDIVIDUAL LIBERTY WITH THE COMMON GOOD 279–318 (1998) (detailing the history of common carrier regulation); Walter H. Hamilton, *Affection with Public Interest*, 39 YALE L.J. 1089, 1100–01 (1930); *cf.* Rose, *The Comedy of the Commons*, *supra* note 26, *passim* (discussing inherently public property).

163. EPSTEIN, *supra* note 162, at 156, 279–318 (quoting Allnut v. Inglis, 104 Eng. Rep. 206, 208 (K.B. 1810)).

> The paramount concern is the nature of the service, not the conditions of supply. Public convenience and necessity is required of a service because it is a critically important, indispensable input into other economic activity. The function provided by and the network characteristics of transportation and communications industries are conducive to creating the conditions for "affecting the public interest."[164]

2. Public and Social Infrastructure: Understanding the Outputs

When analyzing nonrival inputs, the outputs matter. The typology above defines three infrastructure types based on the nature of the outputs. The value of an infrastructure resource ultimately is realized by consumers of these downstream outputs. It is thus the demand for these outputs that determines demand for the infrastructure.

Recall the economic classification schema discussed in the previous section: Private goods are rivalrously consumed, pure public goods are nonrivalrously consumed, and impure public goods are (non)rivalrously consumed.[165] Two points made in the last section bear repeating. First, the public or private nature of a resource is a function of (non)rivalry—how its capacity adjusts to consumption.[166] If consumption by a person *always* has a negative effect on the consumption opportunities for other potential consumers, then the resource is rivalrously consumed and can be labeled a private good. If consumption by a person *never* has a negative effect on the consumption opportunities for other potential consumers, then the resource is nonrivalrously consumed and can be labeled a pure public good. Finally, if consumption by a person may have a negative effect on the consumption opportunities for other potential consumers depending upon the context, then the resource is (non)rivalrously consumed and can be labeled an impure public good.

Second, the public or private nature of a resource is not a function of excludability.[167] Excludability refers to how costly it

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164. Cooper, *supra* note 27, at 17.

165. *See supra* Part II.A.

166. *See supra* Part II.A.

167. *See supra* note 106 (discussing Demsetz). Some analysts view public goods narrowly in terms of a putative market failure that occurs because consumers, in particular, fail to contribute their optimal or fair share. *See, e.g.*, CORNES & SANDLER, *supra* note 31, at 39 (analyzing public goods as this type of collective action problem). This narrow view implicitly links nonrivalry with free-riding behavior that results from nonexcludability. *See supra* Part II.A. To avoid this mistake, I adopt a more expansive view of public goods. Specifically, I view public goods as resources that have the *potential* to generate posi-

is to prevent someone else from consuming the resource and is relevant to a supply-side analysis of how well the market mechanism will work.

Private goods and public goods (pure and impure) are supplied by the market mechanism with varying degrees of effectiveness. For private goods, the market mechanism generally works well from both the supply and demand sides, assuming markets are competitive. For public goods, the market mechanism may fail from both the supply and demand sides, even if markets are competitive. In some cases, the market may be corrected through institutional intervention. For example, if the costs of exclusion are sufficiently high that undersupply is expected, legal fences may be employed to lessen the costs of exclusion and thereby provide improved incentives to invest in supplying the desired public good.

"Nonmarket goods" refer to those goods that are neither provided nor demanded through the market mechanism; we do not purchase such goods.[168] We may recognize their value but we simply do not rely on the market as a provisional mechanism.[169] Instead, we rely on other provisional mechanisms, including government, community, family, and individuals.

Consider, for example, the preservation of certain resources, perhaps historic or environmental, for future generations. It may be the case that society as a whole considers such an objective to be worthwhile, but for various reasons not discussed in this Article, the market mechanism simply will not accurately measure or respond to societal demand for preservation of this sort. The same can be said for active participation in democratic dialogue; voting; free speech; society-wide education; and redistribution of wealth to aid those in need. Many of the things we collectively value in the United States are nonmarket goods.[170]

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tive externalities, depending on how access to the resources is managed. *Cf.* Demsetz, *Toward a Theory of Property Rights*, *supra* note 31, at 348 ("Every cost and benefit associated with social interdependencies is a potential externality."). As explored in the text below, whether or not this potential ought to be tapped will depend on the institutional setting and overall context.

168. *See* Nicholas E. Flores, *Conceptual Framework for Nonmarket Valuation*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 43, at 27, 27–29, 39.

169. *See id.* at 38–39.

170. *Cf.* CORNES & SANDLER, *supra* note 31, at 51 (discussing "environmental commodities"); Cohen, *Perfect Curve*, *supra* note 47, at 1808–10 (noting difficulties in social value judgments of cultural works). There is some overlap between nonmarket goods and merit goods. While nonmarket goods are not

From the demand side, the important distinction between these outputs—what separates nonmarket goods in particular from public goods—is the means by which they create value for society. The value of public goods is realized upon consumption. That is, upon obtaining access to a public good, a person consumes it and accrues benefits (value or utility). The production of public goods has the potential to generate positive externalities. Whether the benefits are external to production depends upon the conditions of access and the degree to which the producer internalizes the value realized by others upon consumption. For example, consider a flower garden. A person who plants flowers in his front yard creates the potential for positive externalities that may be realized by those who walk by and appreciate their beauty. The view of the flowers is nonrival; consumption by one person does not deplete the view or beauty available for others to consume. Consumption depends upon access, however, and the realization of potential externalities depends upon whether the homeowner builds a fence that effectively obstructs the public's view. If the homeowner builds an effective fence, then he has restricted access and the potential for positive externalities remains untapped. If, on the other hand, the homeowner does not build such a fence, then people who pass by obtain access to the view, consume it, and realize external benefits. I like to refer to such persons as incidental beneficiaries,[171] although some would use derogatory, loaded labels such as "free riders" or even "pirates."[172] At least in the context of an open view of a flower garden, however, we do not really expect people to stop and compensate the homeowner.[173]

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provided for by the market, merit goods are partially provided by the market. *See* RICHARD A. MUSGRAVE, THE THEORY OF PUBLIC FINANCE 13–14 (1959). Merit goods are considered so beneficial to the public that any deficiency in market provision will be compensated for with public provision. *See id.* For example, education could be provided exclusively by the private sector. However, this would leave many children without access to education and cause a subsequent host of social problems when these children do not have the necessary skills to become productive members of society. *See id.* Education is a good whose social merit has been recognized, and therefore both the public and private sectors often provide it to insure more widespread consumption. *See id.*

171. CORNES & SANDLER, *supra* note 31, at 55 ("[T]he only motive that an individual has to provide units of such a [public] good is his or her own private motive of present or future consumption. Enjoyment of those units by others is an incidental by-product.").

172. *See* LESSIG, FREE CULTURE, *supra* note 68, at 53–61 (discussing such labels); Lemley, *Property, Intellectual Property, and Free Riding, supra* note 34 (manuscript at 11–12) (same).

173. Lemley, *Property, Intellectual Property, and Free Riding, supra* note

The homeowner may anticipate and value the fact that persons passing by appreciate the visual beauty and wonderful smells of the garden, but generally the homeowner does not seek compensation or take into account the summed benefits for all. Neither the law nor economic efficiency require complete internalization; external benefits are a ubiquitous boon for society.[174]

By contrast, the value of nonmarket goods is realized in a more osmotic fashion and not through direct consumption. Nonmarket goods change environmental conditions and social interdependencies in ways that increase social welfare.[175] Take, for example, active participation in democratic dialogue or education. While participants may realize direct benefits as a result of their activity, nonparticipants (nonconsumers) also benefit—not because they also may gain access to the good (dialogue or education), but instead because of the manner in which dialogue or education improves societal conditions. As I discuss in more detail in Part IV, active participation in online discussions regarding political issues such as the Iraq war and the 2004 presidential election benefit participants as well as those who never log onto the Internet.[176]

In sum, the production of public goods has the potential to generate positive externalities for nonpaying consumers (incidental beneficiaries or free riders), and the production of nonmarket goods generates diffuse positive externalities, often realized by nonparticipants or nonconsumers.

3. Public and Social Infrastructure: Understanding the Demand-Side Analysis

Public and social infrastructure resources are used to produce public goods and nonmarket goods, respectively.[177] For much of the analysis that follows, I group public and social infrastructure together because the demand-side problems and arguments for commons management generally take the same form.

For both public and social infrastructure, the ability of competitive output markets to effectively create and process in-

34 (manuscript at 19–23).

174. *See id.* (using the flower bed example and making the same argument more generally with respect to internalization of positive externalities).

175. *See* CORNES & SANDLER, *supra* note 31, at 51.

176. *See infra* Part IV; *see also infra* Part III.A (discussing how a family fishing trip may generate nonmarket goods such as family values).

177. I discuss examples of them throughout Parts III and IV.

formation regarding demand for the nonrival input is less clear than in the case of commercial infrastructure. Competitive output markets will not necessarily work well in generating demand information for the required inputs in upstream markets.

Infrastructure users that produce public goods and nonmarket goods suffer valuation problems because they generally do not fully measure or appropriate the (potential) benefits of the outputs they produce and consequently do not accurately represent actual social demand for the infrastructure resource.[178] Instead, for public and social infrastructure, "demand [generated by competitive output markets will] tend[ ] to reflect the individual benefits realized by a particular user and not take into account positive externalities."[179] As I noted in an earlier article:

> To the extent that individuals' willingness to pay for [access to infrastructure] reflects only the value that they will realize from an [output], the market mechanism . . . will not [fully] take into account (or provide the services for) the broader set of social benefits attributable to the public goods[, nonmarket goods,] and network externalities. [Infrastructure consumers] will pay for [access to infrastructure] to the extent that they benefit (rather than to the extent that society benefits) [from the outputs produced].[180]

Difficulties in measuring and appropriating value generated in output markets thus translates into a valuation or measurement problem for infrastructure suppliers.[181] As

178. I say *potential* benefits to remind the reader that once created, public goods have the potential to generate positive externalities. *See supra* Part II.B.2. In addition, it bears emphasizing that the inability to fully appropriate the potential benefits of public goods and nonmarket goods is not remedied by full excludability. As noted in the previous section, exclusion facilitates conditioning access to something upon payment. But absent perfect price discrimination, where sellers match the price of their goods to each consumer's willingness to pay, the full range of potential benefits may not be realized or appropriated because some consumers may be priced out of the market.

179. Frischmann, *Internet Infrastructure*, *supra* note 42, at 51; *see also* LANDES & POSNER, POLITICAL ECONOMY, *supra* note 68, at 16. Landes and Posner untangle this concept:

> One possible explanation for the asymmetry in stakes between copyright owners and public domain publishers is that the public domain really is not worth much—that we have been exaggerating the dependence of authors and inventors (especially the former) on previously created works. But this suggestion confuses private with social value. Public domain works have less private value than copyrightable works, because they cannot be appropriated. They may have great social value.

Id.

180. Frischmann, *Internet Infrastructure*, *supra* note 42, at 55.

181. For an illustration, see *infra* Part III.A (the lake example).

Yochai Benkler has emphasized, output producers do not always seek to measure or appropriate the value they create; they may participate in a form of decentralized, nonmarket production (for example, peer-to-peer production) that depends on access to the infrastructure, but not for the immediate purpose of creating appropriable benefits.[182] Such productive activity generates positive externalities for society as a whole, and may be part of a structural shift in our society's industrial and cultural economies.[183]

To further complicate matters, for some infrastructure resources, and particularly those that act as inputs into cumulative production processes, there may be considerable uncertainty as to what types of downstream applications may arise in the future.[184] Prospective uncertainty can exist along various dimensions that affect investment and management decisions.[185] Such uncertainty complicates decision making and increases transaction costs (e.g., costs associated with identifying and dealing with future contingencies). Moreover, this uncertainty may deter market actors from becoming market producers.[186]

All of these factors suggest that competitive output markets may fail to accurately manifest demand for public and social infrastructure because of the presence of demand-side externalities. To better understand this dynamic, the next section compares infrastructure and network effects, both of which involve demand-side externalities.

182. *See* Benkler, *Coase's Penguin*, *supra* note 14, at 378–81; Benkler, *Freedom in the Commons*, *supra* note 13, at 1251; Benkler, *The Political Economy of Commons*, *supra* note 58, at 7.

183. *See* Benkler, *Coase's Penguin*, *supra* note 14, at 378–81; Benkler, *Freedom in the Commons*, *supra* note 13, at 1251.

184. For an illustration, see *infra* Part III.B (the basic research example).

185. *See, e.g.*, Frischmann, *Innovation and Institutions*, *supra* note 33, at 362, 366–67, 374–75 & n.104; Scotchmer, *Standing on the Shoulders of Giants*, *supra* note 97, at 31–32 (uncertainty makes ex ante contracting between input suppliers and output producers difficult); Flores, *supra* note 168, at 47 ("[D]emand for the environment has dynamic characteristics that imply value for potential use, though not current use, and that trends for future users need to be explicitly recognized in order to adequately preserve natural areas." (discussing an argument from J.V. Krutilla, *Conservation Reconsidered*, 57 AM. ECON. REV. 777 (1967))).

186. Market actors may be averse to uncertainty itself. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 375 n.109 (citing to studies of risk aversion of decision makers).

D. NETWORK EFFECTS

Most, if not all, traditional infrastructure resources are networks.[187] Economists have devoted substantial effort in recent years to unravel the peculiar economic features of networks, commonly referred to as "network effects."[188] Interestingly, much like the analysis of infrastructure in this Article, network economists realize that many nonnetwork industries exhibit network effects and have extended their analysis accordingly.[189] Nicholas Economides, a pioneering network economist, provides the following explanation of networks: "Networks are composed of complementary nodes and links. The crucial defining feature of networks is the complementarity between the various nodes and links. A service delivered over a network requires the use of two or more network components. Thus, network components are complementary to each other."[190]

Network effects are demand-side effects that often, though not always, result in positive externalities (generally referred to as network externalities).[191] Network effects exist when the utility to a user of a good or service increases with the number of other people using it, either for consumption or production

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187. *See* Nicholas Economides, *The Economics of Networks*, 14 INT'L J. INDUS. ORG. 673, 673–74 (1996) ("Formally, networks are composed of links that connect nodes. It is inherent in the structure of a network that many components of a network are required for the provision of a typical service. Thus, network components are complementary to each other."). Amitai Aviram observes that "[o]ften, though not always, realization of network effects requires interconnection between the users. The institution that facilitates interconnection between users of a good or service exhibiting network effects, thus enabling the realization of the network benefits, is called a network." Amitai Aviram, *Regulation by Networks*, 2003 BYU L. REV. 1179, 1182. Traditional infrastructure resources often act as such a network.

188. *See generally supra* note 187; Nicholas Economides, *Network Externalities, Complementarities, and Invitations to Enter*, 12 EUR. J. POL. ECON. 211, 213 (1996).

189. Economides, *The Economics of Networks*, *supra* note 187, at 673.

190. Nicholas Economides, Competition Policy in Network Industries: An Introduction 4 (June 2004) (NET Institute Working Paper #04-23), *at* http://ssrn.com/abstract=386626.

191. Michael L. Katz & Carl Shapiro, *Systems Competition and Network Effects*, J. ECON. PERSP. 93, 96–100 (1994); *see also* Michael L. Katz & Carl Shapiro, *Network Externalities, Competition, and Compatibility*, 75 AM. ECON. REV. 424, 436 (1985). Economists often define network effects as "increasing returns to scale in consumption." Economides, Competition Policy in Network Industries: An Introduction, *supra* note 190, at 5.

(specifically, to produce functionally compatible goods).[192] Economists differentiate between direct and indirect network effects, which arise on so-called actual and virtual networks, respectively. Direct network effects arise because the number of connections an end-user (consumer) can make increases with the size of the network. Standard examples of goods that exhibit direct network effects include telephones and fax machines. As Mark Lemley and David McGowan have explained:

> [O]wning the only telephone or fax machine in the world would be of little benefit because it could not be used to communicate with anyone. The value of the telephone or fax machine one has already purchased increases with each additional purchaser, so long as all machines operate on the same standards and the network infrastructure is capable of processing all member communications reliably.[193]

Basically, the idea is: "the more the merrier."[194]

Indirect network effects arise under similar conditions except that it is not the number of connected end-users that generates value, but rather it is the increased availability of compatible, interoperable, and thus complementary goods.[195] "Computer software is the paradigm example."[196] Indirect network effects in the software industry may arise from horizontal compatibility, such as the compatibility between word processing software (e.g., WordPerfect and Microsoft Word),[197] and from vertical interoperability, as in the case of operating sys-

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192. *See* Lemley & McGowan, *supra* note 54, at 488–94; Economides, Competition Policy in Network Industries: An Introduction, *supra* note 190, at 5 ("A market exhibits network effects (or network externalities) when the value to a buyer of an extra unit is higher when more units are sold, everything else being equal.").

193. Lemley & McGowan, *supra* note 54, at 488–89.

194. Rose, *The Comedy of the Commons*, *supra* note 26, at 768. Congestion may act as a significant constraint. *See* Aviram, *supra* note 187, at 1201 n.71. As Aviram notes:

> Congestion is a major limit on efficient scales in rivalrous networks, i.e., networks in which, besides the positive network externality, there is a negative externality imposed by an additional member of the network on the other members. Rivalrous networks include, inter alia, cellular phones, broadband Internet and peer-to-peer information networks. Nonrivalrous networks, such as languages, PC or video cassette standards, etc., do not suffer from congestion; it is no more difficult for me to express myself in English merely because many millions of additional people also express themselves in English.

Id.; *see also* Lemley & McGowan, *supra* note 54, at 497.

195. Economides, Competition Policy in Network Industries: An Introduction, *supra* note 190, at 5.

196. Lemley & McGowan, *supra* note 54, at 491.

197. *Id.*

tems and application programs (e.g., Microsoft Windows and word processing software).[198] Mark Lemley and David McGowan explained it as follows:

> [S]oftware may be subject to "increasing returns" based on positive feedback from the market in the form of complementary goods. Software developers will write more applications programs for an operating system with two-thirds of the market than for a system with one-third because the operating system with the larger share will provide the biggest market for applications programs. The availability of a broader array of application programs will reinforce the popularity of an operating system, which in turn will make investment in application programs compatible with that system more desirable than investment in application programs compatible with less popular systems. Similarly, firms that adopt relatively popular software will likely incur lower costs to train employees and will find it easier to hire productive temporary help than will firms with unpopular software. Importantly, the strength of network effects will vary depending on the type of software in question. Network effects will be materially greater for operating systems software than for applications programs, for example.[199]

Nicholas Economides has noted that the "key reason for the appearance of network externalities is the complementarity between network components."[200] The essential difference between direct and indirect effects is whether "customers are identified with components," in which case the effect is direct.[201]

Although both types of network effects are prevalent for infrastructure resources and may generate significant positive externalities, network externalities are not the only type of demand-side externalities generated by infrastructure. The other positive externalities generated by infrastructure resources may be attributable to the production of public goods and nonmarket goods by end-users who obtain access to the infrastructure resource and use it as an input.[202]

There is a critical difference between network effects and "infrastructure effects"[203] and the resulting types of external-

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198. *See* Phillip J. Weiser, *The Internet, Innovation, and Intellectual Property Policy*, 103 COLUM. L. REV. 534, 564–68 (2003).

199. Lemley & McGowan, *supra* note 54, at 491–92 (footnotes omitted). Lemley and McGowan also discuss other examples of virtual networks. *Id.* at 491–94.

200. Economides, Competition Policy in Network Industries: An Introduction, *supra* note 190, at 6.

201. *Id.*

202. *See supra* Part II.B.

203. I hesitate to use this term because it is very difficult to isolate a nar-

ities. Network effects tend to increase consumers' willingness to pay for access to the resource.[204] By definition, network effects arise when users' utilities increase with the number of other users.[205] Economists assume that consumers appreciate the value created by network effects and thus are willing to pay more for access to the larger network, which may lead to the internalization of some network externalities.[206] Thus, although the generally applicable *law of demand* holds that "the willingness to pay for the last unit of a good decreases with the number of units sold,"[207] the opposite may hold true for goods that exhibit network effects. The presence of network effects may cause the demand curve to shift upward as the quantity of units accessed (sold) increases, leading to an upward-sloping portion of the demand curve.[208]

Infrastructure effects do not necessarily increase users' willingness to pay for access to the infrastructure resource. As discussed above, a user's willingness to pay for access to the infrastructure resource is limited to benefits that can be obtained by the user, which depends upon the nature of the outputs produced, the extent to which such outputs generate positive externalities, and the manner in which those externalities are distributed. Infrastructure effects resemble indirect network effects in the sense that a larger number or a wide variance of applications may lead to an increase in consumers' valuation of the infrastructure or network.[209] However, the externalities generated by public and social infrastructure are even more indirect; they are diffuse, derived from public and nonmarket goods, and not simply a function of increased availability of desired end-users or end-uses. Further, the externalities generated by public and social infrastructure often positively affect the utility of nonusers, that is, members of society who are not

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row definition. For now, I use "infrastructure effects" to refer to comedy of the commons type situations where open access to a resource generates positive externalities through the production of public goods and nonmarket goods. *See generally* Rose, *The Comedy of the Commons*, *supra* note 26.

204. Economides, Competition Policy in Network Industries: An Introduction, *supra* note 190, at 6.

205. *See id.* at 7.

206. *See id.* at 11; Spulber & Yoo, *supra* note 43, at 926.

207. Economides, Competition Policy in Network Industries: An Introduction, *supra* note 190, at 6.

208. *Id.*; Economides, *The Economics of Networks*, *supra* note 187, at 682.

209. *See* Aviram, *supra* note 187, at 1197.

using the infrastructure itself also benefit.[210] In a sense, the positive externalities generated by the outputs are closely connected to the nature of the outputs and only loosely connected to the complementary relationship between the infrastructure and the output. This is important because the prospect of infrastructure suppliers internalizing complementary externalities is much less likely,[211] making the possibility of a demand-side market failure much more likely.

E. THE CASE FOR INFRASTRUCTURE COMMONS

At this point, we have developed an economic theory of infrastructure that provides a better understanding of societal demand for infrastructure resources. The key insights from this analysis are (1) that infrastructure resources generate value when used as inputs into a wide range of productive processes, and (2) that the outputs from these processes are often public goods and nonmarket goods that generate positive externalities benefiting society as a whole. Managing such resources in an openly accessible manner may be socially desirable when doing so takes advantage of nonrivalry and facilitates these types of downstream activities.[212]

The case for commons management must be evaluated carefully and contextually. Broad prescriptions are not easily derived. To facilitate analysis, I developed an infrastructure ty-

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210. I discuss a few examples below. *See infra* Part III.A (the lake example: discussing positive externalities associated with development of family values while on a family fishing trip); Part III.B (the basic research example: discussing positive externalities associated with saving lives); Part IV (the Internet example: discussing positive externalities associated with online democratic discourse and the derivative benefits realized by members of society that never log onto the Internet).

211. On the theory of "internalizing complementary externalities," see Farrell & Weiser, *supra* note 6, at 89, 100–26. *See also* Douglas Lichtman, *Property Rights in Emerging Platform Technologies*, 29 J. LEGAL STUD. 615, 617 (2000).

212. Benkler explores the possibility of managing nonrival and partially nonrival inputs in an openly accessible manner. *See* Benkler, The Commons as a Neglected Factor of Information Policy, *supra* note 5, *passim* (addressing information and spectrum). Benkler implicitly recognized that spectrum can be managed in a fashion that overcomes potential rivalry and takes advantage of nonrivalry. *See id.* at 21; *see also* Yochai Benkler, *Some Economics of Wireless Communications*, 16 HARV. J.L. & TECH. 25, 79 (2002); Benkler, *Overcoming Agoraphobia*, *supra* note 13, at 361–62. More generally, Benkler has explored the advantages of commons-based information production. *See, e.g.*, Benkler, *Coase's Penguin*, *supra* note 14; Benkler, *From Consumers to Users*, *supra* note 14.

pology to distinguish between commercial, public, and social infrastructure, based upon the nature of outputs and the potential for positive externalities. This section sets forth the economic arguments for managing these different types of infrastructure in an openly accessible manner.

For commercial infrastructure, antitrust principles provide a sufficient basis for determining whether open access is desirable because competitive markets (for both inputs and outputs) should work well.[213] Downstream producers of private goods can accurately manifest demand for infrastructure because consumers realize the full value of the goods (i.e., there are no externalities) and are willing to pay for such benefits. Accordingly, from the demand side, there is less reason to believe that government intervention into markets is necessary, absent anticompetitive behavior. The special case of natural monopolies, in which a single producer supplies commercial infrastructure, triggers similar considerations over the risk of anticompetitive behavior (e.g., leveraging into output markets), pricing issues for the input, and fear of less than socially desirable output.[214]

For public or social infrastructure, the case for commons management becomes stronger for a few reasons. First, output producers are less likely to accurately manifest demand due to information/appropriation problems. It is difficult for these producers to measure the value created by the public or nonmarket good outputs; producers of such outputs are not able to appropriate the full value because consumers are not willing to pay for the full value (due to positive externalities); and such producers' willingness to pay for access to the input likely will be less than the amount that would maximize social welfare.

For purposes of illustration, let us engage in a brief thought experiment. For each infrastructure type, (1) imagine a ranking of uses based on consumers' willingness to pay, and (2) imagine a similar ranking based instead on social value generated by the use. For commercial infrastructure, we should expect significant overlap if not identical ordering for the two rankings. For public and social infrastructure, the rankings likely are quite different because there may be users with low

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213. *See supra* Part II.C.1; *see also* Farrell & Weiser, *supra* note 6, *passim*; Philip J. Weiser, *Toward a Next Generation Regulatory Strategy*, 35 LOY. U. CHI. L.J. 41, 74–84 (2003).

214. *See supra* note 81 (discussing natural monopolies).

willingness to pay, but uses that generate great social value (much of which is externalized).[215]

Social surplus (i.e., the amount by which the social value exceeds the private value) may result from a "killer app," such as e-mail or the World Wide Web, that generates significant positive externalities, or from a large number of outputs who generate positive externalities on a smaller scale. That is, in some situations, there may be a particularly valuable public (or nonmarket) good output that generates a large social surplus, and in others, there may be a large number of such outputs that generate small social surpluses. Both types of situations are present in the Internet context. While the "killer app" phenomenon appears to be well understood, the small-scale but widespread production of public and nonmarket goods by end-users that obtain access to the infrastructure appears to be underappreciated (and undervalued) by most analysts.[216] Yet in both cases, there may be a strong argument for managing the infrastructure resource in an openly accessible manner to facilitate these productive activities.

The social costs of restricting access to public or social infrastructure can be significant and yet these costs evade observation or consideration within conventional economic analysis. Initially, we may analyze the issue as one of high transaction costs and imperfect information. Yet, even with perfect information and low or no transaction costs with respect to input suppliers and input buyers, input buyers would still not accurately represent social demand because it is the benefits generated by the relevant outputs that escape observation and appropriation.

To the extent that infrastructure resources can be optimized for particular applications, which is often the case, there is a risk that infrastructure suppliers will favor existing or expected applications.[217] If we rely on the market as the provi-

215. *See infra* appendix figures 1–3.

216. *See infra* Parts III, IV (illustrating this dynamic in the context of lakes, basic research, and the Internet).

217. As we will see in Part IV, the Internet provides a wonderful example of how an infrastructure resource can be optimized for different types of applications. As noted in Part I.B, the degree and terms of access to infrastructure can be thought of as definitional characteristics of the resource itself. Does society demand an open infrastructure, a closed infrastructure, or something in between? Does society demand an infrastructure designed to be neutral to the types of end-uses or end-users that may require access? We will explore these issues in Part IV in the context of the ongoing debate over network neutrality

sional mechanism, there is a related risk that infrastructure suppliers will favor applications that generate appropriable benefits at the expense of applications that generate positive externalities.[218] Even putting aside the generation and processing of demand signals, it remains unclear whether markets will operate efficiently with respect to the supply of public and social infrastructure. There may be significant transaction cost problems that hamper markets.[219] For example, transaction costs associated with price setting, licensing, and enforcement may increase as the variance of public good and nonmarket good outputs increases.[220]

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and the future of the end-to-end architecture of the Internet.

Still, it is worth noting that other infrastructure resources face similar issues. As I explored in an earlier article, we might ask whether federally funded scientific research ought to be directed at commercial ends, noncommercial ends, or no particular ends at all. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 395–416. I argued that the Bayh-Dole Act represented a shift in federal policy towards a regime of more restrictive access to research results through the issuance of intellectual property rights and at the same time, the Act, as well as funding priorities, suggested that Congress was seeking to direct scientific research towards commercial ends. *See id.* at 406–07; *see also* Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77, 109–15 (1999) [hereinafter Rai, *Regulating Scientific Research*]; Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 291–314 (2003); Reichman & Uhlir, *supra* note 67, at 341–440; Robert P. Merges, *Property Rights Theory and the Commons: The Case of Scientific Research*, *in* SCIENTIFIC INNOVATION, PHILOSOPHY, AND PUBLIC POLICY 145 (Ellen Frankel Paul et al. eds., 1996); *cf.* LANDES & POSNER, POLITICAL ECONOMY, *supra* note 68, at 15–17 (illustrating through public choice analysis how copyright law itself may be biased toward appropriable benefits).

218. I discuss this bias below. *See infra* Part III; *see also* Benkler, *Freedom in the Commons*, *supra* note 13, at 1253–54 (discussing various market biases).

219. *See, e.g.*, Arti K. Rai, *Proprietary Rights and Collective Action: The Case of Biotechnology Research with Low Commercial Value*, *in* INTERNATIONAL PUBLIC GOODS AND TRANSFER OF TECHNOLOGY UNDER THE GLOBALIZED INTELLECTUAL PROPERTY REGIME (Keith Maskus & Jerome H. Reichman eds., forthcoming May 2005) (manuscript at 2) [hereinafter Rai, *Proprietary Rights and Collective Action*], *available at* http://ssrn.com/abstract=56821; Tassey, *supra* note 144, at 71–72. For an interesting paper on transaction costs, see Driesen & Ghosh, *supra* note 76 (manuscript at 31–34) (defining transaction costs broadly as "the costs of dealing with people" and arguing that transaction costs serve various positive functions).

220. CORNES & SANDLER, *supra* note 31, at 91 (expressing sympathy with the argument that transaction costs may increase as the number of externality recipients increases, but suggesting that a more careful analysis of transaction costs needs to be undertaken); R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960) (discussing the limitations that increasing numbers places upon bargaining).

Economists recognize that there is a case for subsidizing public and nonmarket goods producers because such goods are undersupplied by the market.[221] The effectiveness of directly subsidizing such producers will vary, however, based on the capacity for subsidy mechanisms to identify and direct funds to worthy recipients.

In some cases, open access to the infrastructure may be a more effective—albeit blunt—means for supporting such activities than targeted subsidies. Open access is not necessarily a subsidy,[222] but it eliminates the need to rely on either the market or the government to "pick winners"[223] or uses worthy of access.[224] On one hand, the market picks winners according to the amount of appropriable value generated by outputs and consequently output producers' willingness to pay for access to the infrastructure.[225] On the other hand, to subsidize production of public goods or nonmarket goods downstream, the government needs to pick winners by assessing social demand for such goods based on the social value they create.[226] As illustrated in Parts III and IV, the inefficiencies, information problems, and transaction costs associated with picking winners under either system may justify managing public and social infrastructure resources in an openly accessible manner.

F. PRICE DISCRIMINATION

Perfect price discrimination could eliminate some of the demand-side concerns that I have raised.[227] Perfect price discrimination means that output producers who desire access to the infrastructure are granted access individually at their re-

221. *See* CORNES & SANDLER, *supra* note 31, at 153–58.

222. Depending on the context, open access may operate as the functional equivalent of a subsidy.

223. I thank Lauren Gelman of the Stanford Law School Center for Internet and Society for focusing my attention on the notion of "picking winners."

224. Lessig has emphasized that a commons avoids relying on market incumbents to decide the future of innovation. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 14. Benkler has emphasized that a commons avoids relying on the market (and property rights holders) more generally. Benkler, *The Political Economy of Commons*, *supra* note 58, at 7.

225. *See supra* Part II.B–D (discussing this dynamic).

226. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 386–91 (discussing government assessment of demand for public goods).

227. *See generally* Demsetz, *The Private Production of Public Goods*, *supra* note 100.

spective willingness to pay.[228] Perfect price discrimination typically is not feasible in the real world, however.[229] Although imperfect price discrimination may be possible in particular contexts, the welfare implications of imperfect price discrimination are ambiguous and vary considerably by context.[230] Accordingly, while issues pertaining to price discrimination may be important in specific contexts, they are beyond the scope of this Article.

Nonetheless, it is worth noting that the "path to price discrimination" may be fraught with peril for society. Pricing practices in many industries evolve over time.[231] When unchecked by competition or the government, producers often drive toward price discrimination for an intuitively obvious reason—differential pricing allows the producer to extract a greater proportion of the surplus than under uniform pricing. This can be a good thing for society. For example, the ability to extract a greater proportion of the surplus may lead to increased private incentives to invest in producing and maintaining infrastructure. Yet the evolutionary path to price discrimination within an infrastructure industry may entail hidden social costs because of the likelihood that investments, technological design, and even the regulatory system can be optimized along the way in favor of commercial outputs (and the producers of such outputs) that generate observable and appropriable benefits. The constant pull of market forces exerts tremendous pressure on infrastructure providers and the government to direct investments to capacity expansion, technological upgrades to the infrastructure, and research and development toward commercial

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228. In theory, then, for nonrival infrastructure resources, all output producers obtain access, even if their willingness to pay is quite low. For partially (non)rival infrastructure resources, the analysis becomes more complicated because infrastructure capacity may be constrained. Perfect price discrimination will not necessarily lead to a socially optimal allocation of access because low willingness to pay/high social value uses may be excluded. Further, there may be inadequate incentives for infrastructure providers to invest in capacity expansion that would be socially optimal but not privately desirable. Of course, there may be inadequate incentives under a commons regime as well. *See infra* Part IV.

229. Economides, *The Economics of Networks*, *supra* note 187, at 682 ("Clearly, the welfare maximizing solution can be implemented through perfect price discrimination, but typically such discrimination is unfeasible.").

230. *See* JEAN TIROLE, THE THEORY OF INDUSTRIAL ORGANIZATION 139, 149 (1988) (concluding that the welfare effects of imperfect price discrimination—technically, second and third degree price discrimination—are "ambiguous" and may be "socially suboptimal," depending upon the context).

231. *See generally* Odlyzko, *supra* note 29.

ends.[232] The same pressure also has public choice implications and may affect the shape of law and regulation.[233]

III. ILLUSTRATIVE EXAMPLES: ENVIRONMENT AND INFORMATION

To provide a bit more context to what may seem like an abstract economic theory, this Part provides a few descriptive examples of nontraditional infrastructure resources. I focus on environmental and information resources. In doing so, I elaborate on a number of the issues raised in the previous Parts.

In an important article, *A Politics of Intellectual Property: Environmentalism for the Net?*, James Boyle argued that "we need a politics, or perhaps a political economy, of intellectual property," modeled after the environmental movement.[234] Boyle's vision for the information or public domain movement is one that parallels and learns from the environmental movement, and is driven by shared normative principles of protecting diffuse social benefits and overcoming collective action problems.[235]

Scholars have begun borrowing from the environmental movement,[236] but the borrowing thus far is founded mainly upon rhetorical or descriptive metaphors and analogies (e.g., commons or information ecosystems). While such an analysis is a useful starting point, substantive comparisons of both resource problems and solutions are lacking.[237] This Article takes

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232. *See generally infra* Part IV.

233. *See* Nelson, *supra* note 42, *passim*.

234. James Boyle, *A Politics of Intellectual Property: Environmentalism for the Net?*, 47 DUKE L.J. 87, 87 (1997).

235. *Id.* at 108–12.

236. *See id.* (intellectual resources); Boyle, *Second Enclosure Movement*, *supra* note 97 (same); Benkler, *Battle over the Institutional Ecosystem*, *supra* note 14 (the Internet); Patrick S. Ryan, *Application of the Public-Trust Doctrine and Principles of Natural Resource Management to Electromagnetic Spectrum*, 10 MICH. TELECOMM. & TECH. L. REV. 285 (2004) (spectrum). For an interesting mapping between the environment, information, and the Internet, see Jim Chen, *Webs of Life: Biodiversity Conservation as a Species of Information Policy*, 89 IOWA L. REV. 495 (2004); Symposium, *Intellectual Property, Sustainable Development, and Endangered Species: Understanding the Dynamics of the Information Ecosystems*, Michigan State University-Detroit College of Law (Mar. 2004), *information available at* http://www.law.msu.edu/ipclp/conference04/index.html.

237. *But see* Frank A. Pasquale, The Market Effects of an Intellectual Commons: Lessons from Environmental Economics for the Law of Copyright 28–38 (Aug. 29, 2004) (Seton Hall Public Law Research Paper No. 12) (apply-

a step in the direction of analytic comparison by developing a substantive economic basis for mapping environmental principles to information and Internet disciplines. Moreover, it may be the case that the truly important borrowing that should take place is not from descriptive metaphors, but from normative principles. The precautionary principle, intergenerational equity, and sustainable development, for example, have gained traction in the environmental area because of theoretical and empirical support. These principles may be more powerful than rhetoric if they are analytically justified.[238]

The infrastructure theory developed in this Article builds a substantive bridge between these disciplines that is grounded in economics. Building this bridge provides an important foundation for mapping normative principles across disciplines. This Article focuses on the principle of managing fundamental resources in an openly accessible manner.

There are interesting parallels between environmental and information infrastructure resources; both are inputs into complex dynamic processes—natural ecosystem processes and cumulative intellectual processes, social and cultural processes, learning processes—that have the potential to yield significant positive externalities that benefit society as a whole. Sustaining these fundamental resources in an openly accessible manner is critical to realizing this potential.

A. THE ENVIRONMENT AS INFRASTRUCTURE

At a very general level, the environment can be viewed as natural infrastructure that is an essential input into a wide range of human and natural productive processes. The environment "provides service flows used by people in the production of goods and services, such as agricultural output, human health, recreation, and more amorphous goods such as quality of life."[239] It also provides service flows essential to natural processes, including a wide variety of ecosystem services such

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ing substantive environmental models to information and intellectual property issues), *at* http://papers.ssrn.com/abstract=584682.

238. To be clear, James Boyle was not advocating the borrowing of rhetoric alone. He argued more broadly for political and social change and for a reconceptualiztion of the intellectual debate. *See* Boyle, *A Politics of Intellectual Property: Environmentalism for the Net?*, *supra* note 234, *passim*.

239. Richard L. Revesz & Robert N. Stavins, *Environmental Law and Policy*, *in* THE HANDBOOK OF LAW AND ECONOMICS (forthcoming 2005) (manuscript at 9), *at* http://ssrn.com/abstract=552043.

as "purification of air and water, detoxification and decomposition of wastes, regulation of climate, regeneration of soil fertility, and production and maintenance of biodiversity."[240] Richard Revesz and Robert Stavins observe that "[t]his effect is analogous to the manner in which real physical capital assets [such as traditional infrastructure] provide service flows used in manufacturing. As with real physical capital, a deterioration in the natural environment (as a productive asset) reduces the flow of services the environment is capable of providing."[241]

While a bird's eye view of the environment is appealing, it is also helpful to focus more acutely on specific environmental resources. Consider, for example, a lake. What makes a lake valuable to society? Like a road system, a lake is socially valuable primarily because it can be used to produce social benefits. Think about the wide variety of uses of many lakes. They can be used for fishing, boating, swimming, and for other recreational activities. Further, lakes can be used as subject matter for artwork, for commerce, for transportation of goods, for waste processing, as a sink for pollution, or as a drinking water source, to name a few. These uses are in addition to the socially valuable role the lake plays in supporting a complex ecosystem.[242]

A lake satisfies all three criteria in the general definition of infrastructure. It may be consumed (non)rivalrously; social demand for access to the lake is driven primarily by downstream productive activities; and the range of goods and services produced downstream varies considerably across the spectrum of public, private, and nonmarket goods. Some of these uses are purely consumptive and some are competing. For example, too much pollution may preclude swimming or ruin a view.[243] Thus, a lake is a partially (non)rival good; it *may* be consumed

240. Gretchen C. Daily et al., *Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems*, ISSUES ECOLOGY, Spring 1997, at 1, 1, *available at* http://www.epa.gov/watertrain/pdf/issue2.pdf; *see* A. Myrick Freeman III, *Economic Valuation: What and Why*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 43, at 1, 3 ("Examples include nutrient recycling, organic material decomposition, soil fertility generation and renewal, crop and natural vegetation pollination, and biological control of agricultural pests.").

241. Revesz & Stavins, *supra* note 239 (manuscript at 9).

242. On the wide variety of socially valuable uses of environmental resources, see generally A PRIMER ON NONMARKET VALUATION, *supra* note 43.

243. The fact that there are competing uses of a resource with finite capacity means that we are dealing with scarcity and trade-offs. *See* Freeman, *supra* note 240, at 1–3.

nonrivalrously, depending upon how it is managed. Viewed from the opposite perspective, downstream uses are potentially rivalrous. From either perspective, it is critical to realize that rivalrousness is not a preordained fact. As noted in Part II.A, whether or not consumption of a partially (non)rival resource is rivalrous turns on the capacity of the resource, the number of users, the amount of capacity consumed by each use, the rate at which capacity is renewed, and thus more generally, on how access and consumption of the resource is managed.[244] In deciding how to manage a partially (non)rival good and deal with inherent scarcity, priorities should vary based on rates of potential congestion and potential value produced by downstream uses.

What is the social value of a lake? Can we measure its value? It is difficult to estimate the social value of a lake, mainly because of the wide variety of downstream uses that generate public and nonmarket goods.[245] Economists have developed various methods to estimate the value of environmental resources, such as stated preference methods and revealed preference methods.[246] These methods have advanced significantly in the past few decades,[247] and are used increasingly in policy and resource management settings.[248] These methods, however, are, at best, useful but incomplete proxies for measuring the social value of environmental resources.[249]

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244. *See supra* Part II.A.

245. *See generally* A PRIMER ON NONMARKET VALUATION, *supra* note 43. As discussed at length by Rose, courts have recognized both the existence of multiple uses of waterways and bodies of waters (e.g., recreation, commercial travel, fishing, and transportation) and the social benefits not captured or well-represented in the marketplace derived from some of these uses. *See* Rose, *The Comedy of the Commons*, *supra* note 26, at 723–50. She argues that doctrines requiring open access to certain resources may be understood as responsive to a "comedy of the commons" situation, where increased access leads to increased social returns (i.e., scale returns). *See id.* at 723.

246. *See* A PRIMER ON NONMARKET VALUATION, *supra* note 43. Stated preference methods, such as contingent valuation, rely on statements made by individuals in response to questions about various hypothetical scenarios. *Id.* at 21, chs. 4–7. Revealed preference methods rely on observations of how people act in actual scenarios. *Id.* at 21, chs. 8–11. *See also* Revesz & Stavins, *supra* note 239 (manuscript at 12–20) (providing an accessible account of these and other methods).

247. *See generally* A PRIMER ON NONMARKET VALUATION, *supra* note 43.

248. *See* Daniel W. McCollum, *Nonmarket Valuation in Action*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 43, at 483.

249. *See* Richard C. Bishop, *Where to from Here?*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 43, at 537, 539 ("[T]rue economic values

As James Salzman and J.B. Ruhl have observed, "environmental law relies almost entirely on proxy measures."[250]

The partially (non)rival nature of the lake itself is only part of the puzzle. The frequently told "tragedy of the commons" story focuses our attention on the dilemma of unconstrained consumption and the risk that congestion (via rivalrous consumption) will rise to a level that the resource cannot sustain.[251] This is a very important demand-side dilemma.[252] Yet a myopic focus on the potential for negative externalities ignores the potential for positive externalities.

Classifying a lake as infrastructure frames the resource problem traditionally encountered with respect to lakes in a broader fashion. Lakes are products of nature, and thus we need not worry about producing lakes. Lakes, however, present a consumption problem because they may be consumed in an unsustainable manner. Accordingly, our goal is to figure out how to manage the resource in a manner that maximizes social welfare. "In its most fundamental form, the environmental management problem faced by society is to choose the mix of environmental and resource service flows that is consistent with the highest possible level of human well-being, that is, the mix with the highest aggregate value to people."[253] As Revesz and Stavins remind us, we live in a world of finite resources and we must therefore consider trade-offs between social investments:

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are unobservable."); Revesz & Stavins, *supra* note 239 (manuscript at 12) (These and other related methods attempt to "infer [individuals'] willingness to trade off other goods (or monetary amounts) for environmental services."); *see also id.* (manuscript at 9) ("[T]he benefits of environmental policy are defined as the collection of individuals' willingness to pay (WTP) for the reduction or prevention of environmental damages or individuals' willingness to accept (WTA) compensation to tolerate such environmental damages.").

250. James Salzman & J.B. Ruhl, *Currencies and the Commodification of Environmental Law*, 53 STAN. L. REV. 607, 623 (2000).

251. *See generally* Hardin, *supra* note 72.

252. I refer to congestion as a demand-side dilemma because it arises as a result of consumption decisions. It is interesting to compare network effects and congestion effects. Network effects arise from the manner in which a user's utility function responds positively to an increase in the number of other users. Congestion effects arise from the manner in which a user's utility function responds negatively to an increase in the number of other users. In a sense, both types of effects are related to the number of consumption opportunities available. For network effects, the number of opportunities increases with the number of users; for congestion effects, the number of opportunities decreases with the number of users because of depletion.

253. Freeman, *supra* note 240, at 3.

> Protecting the environment usually involves active employment of capital, labor, and other scarce resources. Using these resources to protect the environment means they are not available to be used for other purposes. Hence, the economic concept of the value or benefit of environmental goods and services is couched in terms of society's willingness to make trade-offs between competing uses of limited resources, and in terms of aggregating over individuals' willingness to make these trade-offs.[254]

Recognizing that lakes create social value primarily when used as inputs into the production of a wide variety of outputs suggests that the nature of those outputs is important when evaluating these trade-offs. To the extent that public goods and nonmarket goods constitute a significant portion of the potential outputs, we should recognize that the potential for positive externalities generated by such activities may be realized only if the producers of such outputs obtain access to the resource.[255]

Lakes are resources that have the potential to create negative and positive demand-side externalities. Negative externalities may arise in consumption due to congestion, and positive externalities may arise in consumption due to productive use of the lakes to create public goods and nonmarket goods. As the capacity of lakes is finite and cannot be expanded (like some other partially (non)rival resources that also present a similar set of trade-offs), these competing potentialities give rise to a trade-off between open and restricted access to the resource that must be reconciled.[256] How should this trade-off be recon-

254. Revesz & Stavins, *supra* note 239 (manuscript at 9).

255. *See* Freeman, *supra* note 240, at 3 (recognizing that "many service flows are not properly regulated by markets because of their public goods characteristics of nonexcludability and nondepletability, externalities, and other factors").

256. *Cf.* Bell & Parchomovsky, *supra* note 122, at 13–14 (observing that parks are impure public goods that "admit of nonrivalrous uses only to a certain point," and that once conservation is considered to be a use (or anti-use) from which some will derive value, a conflict between incompatible uses arises that is very different from the excessive use problem ordinarily considered to be a tragedy of the commons). Bell and Parchomovsky do not explore why conservation may be a socially valuable use, except to say that it does not deplete the resource and "thus averts the tragedy of the commons." *See id.* at 14. Still, conservation may be viewed as a use that (1) preserves unimpeded access to the resource for nonconsumptive uses that do not deplete the resource (i.e., other compatible uses), and/or (2) preserves the resource for future generations. Each of these perspectives suggests that conservation would be a productive use that has the potential to generate positive externalities for other users. *Cf. id.* at 6 n.23 (suggesting that anticommons regimes used to sustain parks and open space yield positive externalities for adjacent private property owners).

ciled? Can—or should—an infrastructure commons be sustained in this context?

The dominant regulatory approach in the environmental area targets particular consumptive uses of an environmental resource.[257] This approach limits consumption to sustainable levels (at least in theory with the appropriate information), *while simultaneously* preserving an open access/commons regime for other uses. With respect to our hypothetical lake, direct government regulation may target polluting uses of the lake that rivalrously consume its ability to process waste while leaving the lake openly accessible for recreational and other community uses. This does not mean that no pollution is allowed. Rather, it means that various types of pollution are regulated in a manner that sustains access to the resource for other nonpolluting uses.[258]

The same result likely would not occur if we give an exclusive property right in the lake to a private actor and rely on the market mechanism to allocate access to the lake for various users.[259] Suppose the owner decides to exclude recreational users so as to permit a higher degree of pollution in the lake (perhaps within the range that the lake can tolerate but beyond the range permissible to humans and fish). It is tempting to presume that the owner has internalized all of the costs and benefits associated with his or her decisions, and thus conclude that the decision maximizes social welfare.[260] Such reasoning, however, is faulty. The lost benefits to recreational users may ex-

257. Keep in mind that I am not focusing on the institutional means by which consumptive uses are regulated and thus am not distinguishing between command-and-control versus market-based instruments. On such instruments, see Revesz & Stavins, *supra* note 239 (manuscript at 31–55); David M. Driesen, *The Economic Dynamics of Environmental Law: Cost-Benefit Analysis, Emissions Trading, and Priority-Setting*, 31 B.C. ENVTL. AFF. L. REV. 501, 502–07 (2004).

258. I do not mean to suggest that lakes are open access resources for everything except pollution. To the contrary, fishing, boating, and swimming in some lakes may be regulated to prevent congestion and for health and safety reasons. The example is simply intended to illustrate how regulation can be narrowly targeted to curb a particular consumptive, potentially rivalrous use in order to sustain a commons for other uses.

259. The prospect of reaching an optimal outcome through bargaining among potential users is doubtful because we live in a world of imperfect information and high transaction costs. *See* Coase, *The Problem of Social Cost*, *supra* note 220, at 15–19.

260. *See generally* Demsetz, *supra* note 31, at 348–49 ("A primary function of property rights is that of guiding incentives to achieve a greater internalization of externalities.").

ceed the marginal benefits of additional pollution, but the latter may be more easily appropriated than the former. The property owner might not consider the wide variety of downstream uses of a lake because valuing them and appropriating benefits may be too difficult.

To get a basic idea of why this might be so, imagine that you owned one of the Great Lakes. Further, imagine the difficulty in managing access to the lake, even assuming the costs of exclusion are low.[261] In terms of appropriating maximum benefits (so as to maximize your own welfare, a key reason for granting a property right), it should not be surprising that it would be much easier and more profitable to deal with a smaller number of large-scale commercial users rather than a much larger number of small-scale commercial and noncommercial users.[262]

Difficulties in appropriation may be a function of transaction costs associated with dealing with a wide variety of different types of users.[263] Such costs may relate to information acquisition and exchange,[264] negotiation and enforcement of commitments,[265] demand-side coordination and collective action problems,[266] and other related costs.

More importantly, appropriation difficulties may result because the downstream users themselves generate positive externalities that they do not internalize. For example, when I take my family to the lake for a fishing trip, society as a whole

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261. The underlying information problems a single property owner seeking to maximize his or her own welfare faces are similar to those a manager of a public resource faces. It is difficult to even assess the value of various downstream uses of a lake and thus to make decisions about how the resource should be managed. *Cf.* Thomas C. Brown & George L. Peterson, *Multiple Good Valuation*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 43, at 221, 221–22 (noting the need to measure and compare the value of multiple downstream goods).

262. *See* Bell & Parchomovsky, *supra* note 122, at 27–28 (discussing the impact of group size and skewed distribution of benefits on conservation efforts). Bell and Parchomovsky offer an innovative approach to sustaining commons: take advantage of the transaction costs associated with dealing with multiple parties by granting "antiproperty rights" to property owners proximate to the commons. *See id.* at 31–37.

263. *See* Driesen & Ghosh, *supra* note 76 (manuscript at 31–33).

264. *See id.* at 34; Daniel C. Esty, *Environmental Protection in the Information Age*, 79 N.Y.U. L. REV. 115, 140–55 (2004).

265. *See* Driesen & Ghosh, *supra* note 76 (manuscript at 26–29).

266. *See* Demsetz, *Toward a Theory of Property Rights*, *supra* note 31, at 357–59. *See generally* MANCUR OLSON, THE LOGIC OF COLLECTIVE ACTION (2d ed. 1971) (offering a seminal analysis of collective action problems).

accrues external benefits that we (my family) do not capture or necessarily even appreciate. We develop connections with nature and each other, create long-lasting memories, and reinforce cultural and social values that resonate, at least historically, with our society. Sustaining access to the lake for recreational fishing therefore benefits participants directly and nonparticipants (third parties) indirectly. Consider also a pristine view. While appreciation of the view of Lake Michigan yields direct consumptive benefits that people certainly appreciate and value,[267] it also acts as an input into cultural and social processes that yield, among other things, artwork, literature, memories, and culture.[268]

Difficulties in appropriation also may arise in situations where there are simply no human agents engaged in production downstream. For example, socially valuable outputs may be products of natural rather than human processes.[269] As noted above, many environmental resources, including lakes, support a wide range of socially valuable ecosystem services. These services are not produced by human agents, and, the social benefits of such services are diffuse, indirect, and difficult to observe, much less appropriate.[270]

The market mechanism exhibits a bias for outputs that generate observable and appropriable benefits at the expense of

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267. Given the market value of property adjoining the lake, it is clear that these property owners realize and to some extent appropriate substantial benefits from the view. *Cf.* Bell & Parchomovsky, *supra* note 122, at 20–23 (describing the "proximate property principle" which explains the high value of land located near commons).

268. At a macro level, the "identities" of communities surrounding the lake, including the City of Chicago itself, are intimately tied to a particular conception of the lake—that of a fundamental, natural resource accessible for community use.

269. Freeman, *supra* note 240, at 2–3 (describing indirect environmental services that support "biological and ecological production processes that yield value to people").

270. As James Salzman and J.B. Ruhl explain with respect to wetlands:

> The social value of the habitat is absent from the transaction. The ecosystem services provided by the wetlands—positive externalities such as water purification, groundwater recharge, and flood control—are largely ignored. Opinions may differ over the value of a wetland's scenic vista, but they are in universal accord over the contributions of clean water and flood control to social welfare.

Salzman & Ruhl, *supra* note 250, at 612; *cf.* Esty, *supra* note 264, at 162–63 (discussing why it is important to "'see' many environmental problems more clearly").

outputs that generate positive externalities.[271] This is not surprising because the whole point of relying on property rights and the market is to enable private appropriation and discourage externalities.[272] The problem with relying on the market is that potential positive externalities may remain unrealized if they cannot be easily valued and appropriated by those that produce them, even though society as a whole may be better off if those potential externalities were actually produced.

The market mechanism exhibits other biases as well.[273] For instance, because private discount rates tend to be higher than social discount rates, markets tend to be biased toward the short term.[274] Among other things, the divergence between private and social discount rates can lead to current overconsumption of environmental resources without due regard to the costs for future generations. Similarly, such divergence may lead to overinvestment in applied research and commensurate underinvestment in basic research, and technological optimization of the Internet in favor of existing or reasonably foreseeable applications to the potential detriment of yet-to-be-developed applications.[275] Further, incumbent market actors may act strategically to preserve their market positions or to control the direction of innovation.[276] These biases introduce further dynamic complications associated with "path dependence" and the costs of changing directions once a path has been chosen.[277]

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271. In essence, the market "picks winners" based on the amount of appropriable value generated by an output. This does not mean that full appropriation of benefits is necessary for a market to function. *See* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 33) ("[I]ntellectual property law is justified only in ensuring that creators are able to charge a sufficiently high price to ensure a profit sufficient to recoup their fixed expenses. Sufficient incentive, as Larry Lessig reminds us, is something less than perfect control." (citing Lawrence Lessig, *Intellectual Property and Code*, 11 ST. JOHN'S J. LEGAL COMMENT. 635, 638 (1996))).

272. *See, e.g.*, Demsetz, *Toward a Theory of Property Rights*, *supra* note 31, at 348–49; Lichtman, *supra* note 211, at 615–17.

273. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 374–75 (discussing various types of market biases in the context of innovative process market failure).

274. *See id.*

275. *See infra* Parts III.B, IV.

276. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 32–33; *see also* Benkler, *Freedom in the Commons*, *supra* note 13, at 1272–75 (discussing various market biases).

277. *See* Lemley & McGowan, *supra* note 54, 597–98.

This example illustrates how an environmental resource can be viewed as infrastructure. It is hard to classify all lakes as a particular type of infrastructure because the range of productive activities supported by the resource will vary across different lakes.[278] That being said, most lakes play an integral role in supporting natural ecosystems that generate nonmarket goods, and thus may constitute social infrastructure. Equally important, this example illustrates that for consumption problems, such as pollution of an environmental resource, regulation may be targeted to curb the particular activities that can lead to a tragedy without banning them altogether. Instead, by seeking to limit these activities to sustainable levels, government regulation can preserve the open-access nature of the commons for other activities.[279]

Viewing a lake as infrastructure allows us to appreciate the value of the resource as part of a complex resource system. Like traditional infrastructure, a lake is a foundational resource upon which many different productive activities depend. This view also allows us to perceive society's relationship with traditional infrastructure resources in an alternative fashion. Specifically, we might say that, like a lake, traditional infrastructure resources are an integral part of our environment. While not a product of nature, society interacts with and derives value from traditional infrastructure in much the same fashion as it does with a lake.

B. INTELLECTUAL INFRASTRUCTURE

Applying infrastructure theory to information generally delineates a class of intellectual resources that creates benefits for society primarily through the facilitation of downstream productive activity. Of course, not all information is infrastructure.

Many intellectual resources clearly do not fall within the scope of the general definition of infrastructure. Two examples

278. Compare, for example, Lake Michigan, one of the Great Lakes, with Keuka Lake, one of the small Finger Lakes in upstate New York.

279. Of course, government regulation may not be the only means for striking such a balance between open and restricted access. Community norms, common property systems, and antiproperty easements also may be designed to accomplish a similar outcome. *See* LAWRENCE LESSIG, CODE AND OTHER LAWS OF CYBERSPACE *passim* (1999); Smith, *supra* note 59, at 61–67; Heverly, *supra* note 59, at 1178–83; *see also* Bell & Parchomovsky, *supra* note 122, at 19–37 (adding the concept of antiproperty easements to the list of institutions which can manage access to resources).

are worth discussing briefly. First, consider a standard nail. While a nail satisfies the latter two prongs of the definition, it fails to satisfy the first prong because nails are rivalrously consumed and cannot be managed in a way that renders consumption nonrivalrous. What about the *idea* of a nail? Ideas are nonrival goods, and thus it would seem that the idea of a nail must be infrastructure. The idea of a nail is a nonrival input into the production of a *single* output—a tangible nail, which happens to be an input into a wide range of outputs. This example highlights a difficulty with my definition. It is hard to draw lines where there is a chain of cumulative inputs (idea of a nail→nail→range of outputs).[280] Even if the idea of a nail is deemed infrastructure, however, the fact that the output is a private good suggests that it would be classified as commercial infrastructure. This means that the case for open access is quite weak because competitive output markets should work fine from the demand side.[281]

Second, imagine that scientists discover the cure for a particular disease. While this resource is a nonrival input and thus satisfies the first two prongs of the infrastructure definition, the range of outputs is relatively narrow (curing the particular disease and perhaps some related research avenues). While there may be a strong case for open access to such discoveries on social welfare grounds, I would not classify the discovery as infrastructure.

Focusing on information that satisfies all three criteria for infrastructure helps to distinguish different types of information based on the manner in which they create social value. This class of resources deserves careful attention because the benefits of open access (costs of restricted access) may be substantially higher than for information that is not infrastructure. We know that the production of all types of intellectual resources involves cumulative processes. We know that some intellectual resources are more generic and basic, and more fundamental to these cumulative processes. Finally, we know that in the "great balancing act" we call intellectual property law, not all intellectual resources are or should be treated the same. Yet, despite our knowledge of these facts, our struggle

280. This example also reminds us of the important economic differences between nonrival and rival goods and the welfare implications of restricting access to such goods. *See supra* Part II.A (comparing ideas and apples).

281. *See supra* Part II.D. I thank F. Scott Kieff for using this example to poke holes in my theory.

over striking the appropriate balance does not adequately account for the economic differences between intellectual resources.[282]

Consider, for example, basic research.[283] What makes basic research valuable to society? Again, like a road system (and a lake), basic scientific research is socially valuable primarily because of what it facilitates downstream—how it can be used to produce further research.[284] It satisfies all three criteria in the

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282. *See* Mike Carroll, Tailoring Intellectual Property Rights (2004) (working paper, on file with author); Burk & Lemley, *supra* note 97, at 1577–78.

283. There are many other examples to consider. Take, for example, databases. Is a database infrastructure? Not always—it depends on the contents of the database and the distribution of potential uses. A database of used car values is not infrastructure because the range of uses is quite narrow while the Human Genome database is infrastructure because the range of uses is quite wide. We might consider peer-to-peer software, which Raymond Ku has described as infrastructure and analogized to the historic *Charles River Bridge* decision. Raymond Shih Ray Ku, Copyright, the Constitution & Progress 5 (June 2004) (Case Research Paper Series in Legal Studies, Working Paper No. 04-8) (discussing *Proprietors of the Charles River Bridge v. Proprietors of the Warren Bridge*, 36 U.S. (11 Pet.) 420 (1837), *at* http://papers.ssrn.com/abstract=556642. Computer operating system software is a useful example because it is ubiquitous. An operating system, such as Microsoft Windows or Linux, is a nonrival input into wide variety of applications. The operating system and applications are complementary products, and the operating system and many applications exhibit networks effects. Like basic research, the operating system creates value primarily as an input into applications running on end-users' computers—or in common parlance, as a platform upon which applications may run. *See* Bruce Abramson, *Promoting Innovation in the Software Industry: A First Principles Approach to Intellectual Property Reform*, 7 B.U. J. SCI. & TECH. L. 75, 113–16 (2002) (explaining platform-application relationship). Because the applications themselves are public goods—in the technical sense discussed in Part II.A, the operating system qualifies as a public infrastructure. Of course, this does not necessarily mean that operating systems should be managed in an open manner, but it does suggest that there may be social benefits to doing so because of the potential for positive externalities generated by innovative applications. While the development of the Linux operating system and its open source licensing agreement seems to have been driven by a need to free application developers from the control of Microsoft, it also reflects an implicit understanding of the societal benefits derived from open infrastructure. *See* Robert P. Merges, *A New Dynamism in the Public Domain*, 71 U. CHI. L. REV. 183, 193–195 (2004). I leave a more detailed inquiry into various intellectual infrastructure resources for another paper. Brett M. Frischmann, Intellectual Infrastructure (2005) (working paper, on file with author) [hereinafter Frischmann, Intellectual Infrastructure].

284. In discussing the value of basic research, I focus primarily on its instrumental value. One might ask, as a keen reviewer did, whether there also might be some intrinsic value in knowledge for its own sake. I believe there might be, and the same should be said for lakes as well. We should unpack what "value in knowledge for its own sake" means exactly. Knowledge is a human phenomenon, as is valuing knowledge; the value lies somewhere in

general definition of infrastructure and should be classified as public infrastructure: It is nonrival; it creates benefits or value primarily because of the downstream uses, which generally involve the production of additional public goods (e.g., information, knowledge, and learning); and, by definition, there is wide variation in downstream uses.[285] It is difficult to estimate the social value of basic research, primarily because of the wide variety of downstream uses that generate public goods and uncertainty with respect to future directions that the cumulative productive processes may go.[286] Nonetheless, as with many traditional infrastructures, it is well recognized that basic research contributes significantly to economic growth and social welfare.[287]

The nonrival nature of basic research itself is only part of the puzzle, albeit an important one. As noted in the previous section, nonrival resources have infinite capacity and thus do

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human utility functions, and it certainly need not be instrumental. Perhaps we can think of the noninstrumental, intrinsic value as value derived from consumption rather than productive use. Basic research may be consumed directly by humans in the sense that it generates immediate benefits to those that obtain the knowledge; the same can be said for many infrastructure resources because such resources are not exclusively inputs and may generate value via consumption. Nonetheless, as noted above, the second criterion for infrastructure suggests that the bulk of the value derived from the resource is from productive use of the resource. *See supra* Part II.B.

285. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 365–66 (arguing that the difference between basic and applied research is the variance of anticipated applications or uses). *But cf.* WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW 305–06 (2003) [hereinafter LANDES & POSNER, ECONOMIC STRUCTURE] ("Basic research is distinguished from applied research mainly by lacking *immediate* commercial applications."). I agree with Landes and Posner that the distinction between basic and applied research depends upon the certainty with which particular applications are known. For Landes and Posner, "immediate" refers to applications that already exist or are "immediately foreseeable." *See id.* at 306. I am not sure why applied research needs to be commercial, however. I also am curious as to why Landes and Posner believe basic research ceases to be basic upon the discovery of a single commercial application. *See id.* at 306–07. While such a development may render the research result patentable because "a patent on the research will pass the test of utility," *id.* at 306, it does not alter the basic or generic character of the research. Furthermore, as Landes and Posner seem to suggest, granting a patent in this situation may be troublesome from a social perspective precisely because it may stifle other follow-on areas of research. *See id.*

286. *See supra* note 285.

287. *See, e.g.*, LANDES & POSNER, ECONOMIC STRUCTURE, *supra* note 285, at 305–08; Rai, *Regulating Scientific Research*, *supra* note 217; Reichman & Uhlir, *supra* note 67.

not face the consumption problem.[288] Information resources face a well-known supply-side problem; the inability to cheaply exclude competitors and nonpaying consumers (free riders) presents a risk to investors perceived ex ante (prior to production of the good), which could lead to undersupply.[289] The frequently told free-rider story focuses our attention on the dilemma of unconstrained free riding and the risk of undersupply by the market. This is a very important supply-side dilemma. Yet, as discussed in the previous section, a myopic focus on free riding places too much emphasis on market-driven supply and on excludability as the solution.[290] Ultimately, the complicated economic puzzle involves balancing social benefits of granting access (i.e., consumptive and productive use) and social benefits of restricting access (i.e., to overcome free riding and create incentives for private investment in production and dissemination). This is the basic trade-off reflected in the intellectual property literature and discussed in the previous section.[291]

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288. William M. Landes & Richard A. Posner, *Indefinitely Renewable Copyright*, 70 U. CHI. L. REV. 471, 485 (2003); Rose, *Romans, Roads, and Romantic Creators*, *supra* note 64, at 90; R. Polk Wagner, *Information Wants To Be Free: Intellectual Property and the Mythologies of Control*, 103 COLUM. L. REV. 995, 1001 (2003). Posner and Landes point to an interesting demand-side congestion externality in the intellectual property context: "trademark and right-of-publicity cases [are] both examples of intellectual property the value of which can be diminished by consumption." Landes & Posner, *supra*, at 486. In a sense, these cases involve a situation that is akin to a network externality, except that it involves costs.

289. *See supra* Part II.B.

290. *See supra* Part II.A; *see also* Brett M. Frischmann, *Commercializing University Research Systems in Economic Perspective: A View from the Demand Side*, *in* UNIVERSITY ENTREPRENEURSHIP, INTELLECTUAL PROPERTY, AND TECHNOLOGY TRANSFER (JAI Press Series: Advances in the Study of Entrepreneurship, Innovation & Economic Growth, vol. 16 (forthcoming 2005)) (manuscript, on file with author) [hereinafter Frischmann, *Commercializing University Research Systems*].

291. *See supra* Part II.A. There are other trade-offs between social benefits and costs that are reflected in intellectual property law. For example, it is well established that increasing disclosure of information that would remain secret in the absence of patents is a critical function of patent law. *See* Festo Corp. v. Shoketsu Kinzoku Kogyo Kabushiki Co., 535 U.S. 722, 736 (2002) ("[P]atent rights are given in exchange for disclosing the invention to the public."); W.L. Gore & Assoc. v. Garlock, Inc., 721 F.2d 1540, 1550 (Fed. Cir. 1983) ("Early public disclosure is a linchpin of the patent system."); Katherine J. Strandburg, *What Does the Public Get? Experimental Use and the Patent Bargain*, 2004 WIS. L. REV. 81, 81; Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 34 (manuscript at 22–23). This trade-off is a supply-side issue that derives first from the particular provisional mechanism (e.g., the market, the government, or some other alternative) and second from a choice of institution (e.g., trade secret, patent). In the absence of intellectual prop-

When we focus on basic research, however, it is important to recognize that the balance tilts heavily toward access.[292] As with lakes, recognizing that basic research behaves economically as infrastructure—in the sense that it creates social value primarily when used as an input into the production of a wide variety of public good outputs—suggests that the social costs of restricting access to the resource can be significant and yet evade observation or consideration within conventional economic transactions. Others have noted that granting exclusive property rights (e.g., patents) over basic research[293] stifles some downstream research, which can impose substantial social costs.[294] This does not mean that no progress will be made. Some avenues of follow-on research may proceed, for example, by initial researchers or others to whom licenses are granted. The point is that basic research may "be encumbered with excessive licensing fees and transaction costs."[295]

Granting property rights over basic research links management of research results with commercialization and thus introduces the market mechanism's inherent bias for outputs that generate observable (or reasonably foreseeable) and appropriable returns.[296] Thus, in making decisions regarding ac-

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erty—and even in the presence of intellectual property—secrecy is a means of exclusion that private producers may utilize to overcome free-riding risks. *See* JAMES BOYLE, SHAMANS, SOFTWARE AND SPLEENS: LAW AND THE CONSTRUCTION OF THE INFORMATION SOCIETY 42–50 (1996). Secrecy significantly constrains the potential social benefits of nonrivalry because access is severely limited. Comparatively speaking, then, patents open up access to information for consumption and productive use, although the range of productive uses is significantly limited by the patent. As described below, in certain respects, intellectual property can be understood as an institution designed to sustain the information commons. How well the system is designed in another question.

292. *See* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE, *supra* note 20, at 8 n.3.

293. While a significant amount of basic research is not patentable, it appears that "more and more fruits of basic research [can] be patented," LANDES & POSNER, ECONOMIC STRUCTURE, *supra* note 285, at 308. In some areas, at least, both the existence and the prospect of patents have had a significant effect on the research process. *See id.* at 305–08.

294. *See id.*; Scotchmer, *Standing on the Shoulders of Giants*, *supra* note 97, at 32; Merges & Nelson, *On the Complex Economics of Patent Scope*, *supra* note 119, at 869–80. As Robert Merges and Richard Nelson explain, some private firms recognize the value of open access to basic research and have undertaken efforts to place research results in the public domain. *Id.*

295. *See* Merges, *A New Dynamism in the Public Domain*, *supra* note 283, at 188.

296. Not only does this bias affect management of existing research results,

cess, owners face the same set of problems that our hypothetical owner of a lake faces (e.g., transaction costs and uncertainty regarding the prospect of appropriable returns). While downstream uses are not rivalrous in the technical sense (i.e., there is no risk of congestion because basic research is a nonrival input), downstream users may compete with each other to develop and commercialize the research, and thus may demand exclusive licenses. This tension was a major premise behind the Bayh-Dole Act and related legislation.[297]

This competitive dynamic may introduce rivalry in consumption and drive owners to favor uses reasonably expected to generate appropriable returns at the expense of uses more likely to generate positive externalities.[298] This may retard progress in a manner that has substantial social opportunity costs in the sense that socially valuable research paths lie fallow and unexplored. In an earlier article, I argued that this constitutes a special type of market failure, which I named "innovative process market failure," because the failure to pursue potential avenues of research involves hidden costs associated with the cumulative, nonlinear nature of the innovative process.[299]

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but it also has dynamic effects on the research process because the prospect of obtaining a patent may skew researchers' incentives and basic scientific norms. *See* Rai, *Regulating Scientific Research*, *supra* note 217, at 109–13; Frischmann, *Commercializing Universtiy Research Systems*, *supra* note 290; *see also* SUZANNE SCOTCHMER, INNOVATION AND INCENTIVES 127–31 (2004) [hereinafter SCOTCHMER, INNOVATION AND INCENTIVES]. Scotchmer explains:

> [I]t is not easy to compensate the developers of basic technologies. Commercial value generally resides in products that are developed later. If the founders earn some profit, it is only because they can demand licensing fees from later developers. But this requires that later products infringe their patents. Basic scientific knowledge . . . is generally not patentable, in recognition of the fact that the benefits would be hard to appropriate.

Id. at 129. One reason that basic research should be supported by public sponsors rather than private investors "is that the benefits of basic research are hard to appropriate by private parties." *Id.* at 131–32. To the extent that the public goods applications are sufficiently commercializable (applied and commercial), there is an argument that markets should work quite well in manifesting demand for the infrastructure and that the major impediments to maximizing social welfare originate on the supply-side. *See generally id.* at 127–59.

297. *See infra* notes 305–06 and accompanying text.

298. *Cf.* Rai, *Proprietary Rights and Collective Action*, *supra* note 219 (manuscript at 8) ("[I]n university contexts, where the immediately foreseeable payoffs—commercial or academic—from research is often not high, researchers are unlikely to be willing or able to incur high transaction costs in order to gain access to upstream research.").

299. Frischmann, *Innovation and Institutions*, *supra* note 33, at 374; *id.* at

Consider the case of research that has uncertain or low commercial value, which, according Arti Rai, deserves particular attention:

> [I]n the context of research that is demonstrably of low commercial value, there is evidence that upstream proprietary rights have impeded downstream research. Consider the case of research into a malaria vaccine. The disease burden associated with malaria is very significant, on the order of over one million deaths a year. The social value of a malaria vaccine would therefore be quite high. Nonetheless, because the primary market for such a vaccine would be in the developing world, such research is of low commercial value. . . .
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> . . . In the area of agricultural biotechnology, there is perhaps even more compelling evidence that research projects of low commercial value have been significantly delayed, or have not gone forward at all, because of upstream patent rights. Specifically, restricted access to patented technologies has been identified as a significant barrier to development of subsistence crops relevant to the developing world.[300]

More generally, the social costs associated with the market mechanism's inherent bias for outputs that generate observable and appropriable returns may be significant. These costs evade observation because basic research is often an input into and output from cumulative processes involving multiple inputs, multiple outputs, multiple actors, and multiple research avenues heading in different directions. These cumulative processes also involve nonlinear progression, feedback loops, spillovers, and numerous other complications that frustrate modelers and defy simplification.[301] All of these characteristics contribute to information and transaction cost problems that make relying on property-based, market-driven management of basic research results almost outrageous, much like the seem-

376 ("The social costs of [innovative process market failure] are an interesting brand of opportunity costs, ranging from slowed technological development within an industry to significant macroeconomic effects on competitiveness in emerging industries.").

300. Rai, *Proprietary Rights and Collective Action*, *supra* note 219 (manuscript at 8–11). Rai provides a number of specific examples where upstream patents have impeded downstream progress of research with low commercial value. *See id.* Rai also considers whether collective action may alleviate the problem. *See id.*

301. Consideration of these characteristics is beyond the scope of this Article. There is, however, substantial literature in this area. *See, e.g.*, Frischmann, *Innovation and Institutions*, *supra* note 33; Rai, *Regulating Scientific Research*, *supra* note 217, at 124; SCOTCHMER, INNOVATION AND INCENTIVES, *supra* note 296; Scotchmer, *Standing on the Shoulders of Giants*, *supra* note 97.

ingly ridiculous hypothetical of granting ownership of Lake Michigan to an individual property owner.[302]

These are strong reasons to believe that we ought not rely solely on property rights and the market mechanism to allocate access to information in all cases. In some cases, we need to take advantage of information's nonrival character and encourage widespread productive use downstream. But how do we overcome the production problem when we also need to strike a balance between access and control to encourage private investment?

There is a continuum of hybrid solutions—such as grants, procurement, subsidies, regulation, property rights, intellectual property rights, contracts, tax incentives, technology, and social norms—that respond implicitly to the fact that intellectual resources are infrastructure. Moreover, the package of institutional solutions varies according to the type of infrastructure.

For basic research, one prevalent way to avoid the need to balance access and incentives is reliance on government funding. According to William Landes and Richard Posner:

> An enormous amount of basic research is produced every year in the United States and other advanced countries without benefit of patentability. . . . In 1999 half of all basic research in the United States was funded by the federal government, and of the balance 29 percent

302. Edmund Kitch's "prospect theory" of patents simply does not work well for basic research. His theory is premised on two notions: (1) that the property owner will minimize social waste associated with duplicative efforts; and (2) that the property owner will best commercialize and license an invention. *See* Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265, 276–78 (1977). Neither premise, however, holds up with respect to basic research. Wasteful duplication is much less likely to be a problem in the context of basic research because of the multitude of directions and outcomes which grow out of basic research. Also, as discussed in the text, an exclusive focus on commercialization may result in significant social opportunity costs. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 372–73, 374–76; Robert P. Merges, *Rent Control in the Patent District: Observations on the Grady-Alexander Thesis*, 78 VA. L. REV. 359, 381 (1992); SCOTCHMER, INNOVATION AND INCENTIVES, *supra* note 296, at 155. Scotchmer concludes:

> Thus the licensing platform created by a pioneer patent can undermine competition . . . in the "innovation market" . . . and competition among users of the patented knowledge. It might be better not to give such patents. One alternative is public funding, and another is to let a later innovator who needs the pioneer innovation redevelop it. This leads to cost redundancy, but unless the tool is very expensive, such redundancy may be a lesser evil than retarding the development of later products through restrictive joint ventures or raising their price by facilitating collusion.

Id.

was financed by universities and other nonprofit research establishments out of their own funds.[303]

This financing removes the need to rely on private investment and thus eliminates supply-side concerns over free riding. At least in theory, then, the optimal management decision would be to release research results into the public domain to encourage free, widespread, and potentially competitive use downstream.

In reality, this solution depends on the government for both allocation of limited public funds and efficient management of the research results. The government's capacity to execute these functions has been subject to extensive criticism on institutional and public choice grounds. In fact, based in part on the perception of a government with a poor record of managing federally funded research results,[304] Congress enacted a series of legislative reforms, such as the Bayh-Dole Act.[305] These reforms generally aimed to facilitate the transfer of publicly funded technology to the private sector.[306] Most notably, the Bayh-Dole Act permitted and encouraged federally funded researchers to obtain patent rights over their inventions.[307] The rationale for this change was the government's failure to transfer (or persuade contractors to transfer) valuable technology to market actors who would have commercialized the results.[308] Granting researchers patent rights, it followed, would enable them to better manage their inventions.[309] In essence, relying

303. LANDES & POSNER, ECONOMIC STRUCTURE, *supra* note 285, at 306.

304. *See* Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 VA. L. REV. 1663, 1702–04 (1996) [hereinafter, Eisenberg, *Public Research and Private Development*] (explaining and critiquing this perception).

305. *See* Bayh-Dole University and Small Business Patent Procedures Act, Pub. L. No. 96-517, 94 Stat. 3019 (codified as amended at 35 U.S.C. §§ 200–211) (2000); *see also* Stevenson-Wydler Technology Innovation Act of 1980, Pub. L. No. 96-480, 94 Stat. 2311 (codified as amended at 15 U.S.C. §§ 3701–3714 (2000)).

306. On these legislative reforms, see Eisenberg, *Public Research and Private Development*, *supra* note 304, at 1704–09; Rebecca S. Eisenberg, *Technology Transfer and the Genome Project: Problems with Patenting Research Tools*, 5 RISK 163, 163–67 (1994); Frischmann, *Innovation and Institutions*, *supra* note 33, at 406; Rai, *Regulating Scientific Research*, *supra* note 217, at 92–94, 109–15.

307. *See generally* Frischmann, *Commercializing University Research Systems*, *supra* note 290.

308. *See id.*

309. *See* Eisenberg, *Public Research and Private Development*, *supra* note 304, at 1664–66.

on intellectual property to stimulate technology transfer reflected a fundamental shift from one restrictive access regime to another—from government control to private market-driven control. This shift has had a profound effect on basic research efforts. For example, as noted by Walter Powell, there has been a "sea change in the focus of basic research" in life sciences because of commercialization by universities of basic scientific research results.[310] For basic research, however, coupling government funding with a clear dedication to the public domain remains a potentially attractive method for sustaining a commons that relies on neither the government nor the market mechanism to allocate access among the public.

For many other intellectual infrastructure resources, the question of how to strike the appropriate balance between access and incentives is reconciled primarily within the law of intellectual property.[311] I leave a more complete discussion of intellectual property law issues pertaining to intellectual infrastructure for a separate paper,[312] but a brief discussion provides a flavor of how this balance is currently struck, and, at

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310. Walter W. Powell, *Networks of Learning in Biotechnology: Opportunities and Constraints Associated with Relational Contracting in a Knowledge-Intensive Field*, *in* EXPANDING THE BOUNDARIES OF INTELLECTUAL PROPERTY: INNOVATION POLICY FOR THE KNOWLEDGE SOCIETY 251, 263–65 (Rochelle Cooper Dreyfuss et al. eds., 2001); *see also* Rebecca S. Eisenberg, *Bargaining over the Transfer of Proprietary Research Tools: Is this Market Failing or Emerging?*, *in* EXPANDING THE BOUNDARIES OF INTELLECTUAL PROPERTY: INNOVATION POLICY FOR THE KNOWLEDGE SOCIETY, *supra*, at 223 (suggesting that delays and high transaction costs stifle transfers of biotechnology research tools).

311. Striking a balance between access and incentives is explicitly recognized as the central issue of intellectual property law. *See* Sony Corp. of Am. v. Universal City Studios, Inc., 464 U.S. 417, 429 (1984) (Copyright "involves a difficult balance between the interests of authors and inventors in the control and exploitation of their writings and discoveries on the one hand, and society's competing interest in the free flow of ideas, information, and commerce on the other hand"); Bonito Boats, Inc. v. Thunder Craft Boats, Inc., 489 U.S. 141, 146 (1989) ("From their inception, the federal patent laws have embodied a careful balance between the need to promote innovation and the recognition that imitation and refinement through imitation are both necessary to invention itself and the very lifeblood of a competitive economy."); Pfaff v. Wells Electronics, Inc., 525 U.S. 55, 60–62 (1998). "The challenge lies in distinguishing discoveries that are better developed and disseminated through open access from discoveries that are better developed and disseminated under the protection of intellectual property rights." Rai & Eisenberg, *supra* note 217, at 291.

312. *See generally* Frischmann, Intellectual Infrastructure, *supra* note 283.

the same time, provides a point of contrast with the discussion of environmental regulation above.

Intellectual property law is designed, at least in theory, to promote and preserve a sustainable information commons. Intellectual property law creates exclusive rights and thereby facilitates private restrictions on access to new information goods to promote progress, advancement, and continued expansion of the public domain as exclusive rights expire.[313] More importantly, even before an intellectual property right expires, an important balance is struck with respect to short-term restriction on access; restricted access is limited in scope and open access is preserved for certain uses.[314]

First, the public gains access to the newly produced information because it is disclosed. Patents themselves serve as an important means of disclosing inventions to the public;[315] to attain a patent, the patentee must sufficiently describe the invention in the patent application, allowing others to recreate the invention.[316] Competitors may be able to invent around the pat-

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313. By providing an ex post reward in the form of a legally enforceable right to exclude others from using newly produced information, the government lowers the costs of exclusion and thereby creates an incentive for private investors to allocate resources towards information production that might otherwise be too risky due to potential free riding. *See supra* notes 94–97 and accompanying text. The limited duration of intellectual property rights ensures that the protected information will make its way into the public domain eventually. *See* 17 U.S.C. § 302 (2000) (copyright term is life of the author plus seventy years); 35 U.S.C. § 154(a) (2000) (patent term is twenty years from filing).

314. *See, e.g.*, Jessica Litman, *The Public Domain*, 39 EMORY L.J. 965, 1002–03 (1990); LANDES & POSNER, ECONOMIC STRUCTURE, *supra* note 285; *see also* Heverly, *supra* note 59, at 1161–88 (arguing that intellectual property is not pure private property but rather is a semicommons, which is a form of property that recognizes the dynamic relationship between private and public uses of information).

315. It is important to remember that trade secrecy is the primary alternative to patenting and that, in the absence of a patent system, a significant amount of information would arguably remain as privately held and guarded secrets and would not be accessible to the public. *See supra* notes 292–95 and accompanying text. Although copyright does not have an express disclosure requirement, most material protected by copyright is naturally disclosed through consumers' ordinary use of the material. *See* Brett Frischmann & Dan Moylan, *The Evolving Common Law Doctrine of Copyright Misuse: A Unified Theory and Its Application to Software*, 15 BERKELEY TECH. L.J. 865, 874 (2000). Consider, for example, the use of books, articles, or songs. *Id.* Software presents an interesting exception. *Id.*; *see* Julie E. Cohen & Mark A. Lemley, *Patent Scope and Innovation in the Software Industry*, 89 CAL. L. REV. 1, 3–4 (2001).

316. 35 U.S.C. § 112 (2000).

ent, essentially using the information as an input into their own productive activities.

Second, intellectual property law imposes a number of restrictions on the scope of coverage. For example, patents cover functional innovations—one can only patent "a new and useful process, machine manufacture, or composition of matter," or "new and useful improvements"; one cannot patent a pure algorithm or abstract idea.[317] Patented inventions must be reduced to practice, novel, nonobvious, and useful.[318] Copyrights generally cover artistic expression and not functional innovations. One cannot copyright ideas, only expression.[319] To be copyrightable, material must feature an original expression fixated in a tangible media, such as books, film, or sound recordings.[320]

Intellectual property law also places restrictions on the scope of private control over others' use of protected information goods. The best example is fair use in copyright law.[321] Fair use of a copyrighted work expressly encompasses purposes such as criticism, comment, news reporting, teaching, scholarship, and research,[322] and implicitly encompasses many other purposes that further the public interest.[323] Such uses may be excused from copyright infringement under the fair use doctrine.[324]

In the following sense, fair use is the inverse of the environmental regulation discussed earlier: fair use preserves open access for certain productive uses[325] of protected expression while environmental regulation restricts access for certain consumptive uses of an environmental resource, which, in turn, preserves access for certain productive uses. Critically, many of the productive uses of environmental and intellectual infra-

317. 35 U.S.C. § 101 (2000); Diamond v. Chakrabarty, 447 U.S. 303, 309 (1980) ("The laws of nature, physical phenomena, and abstract ideas have been held not patentable.").

318. *Id.* §§ 101–103, 112 (2000).

319. 17 U.S.C. § 102(b) (2000).

320. *Id.* § 102(a) (2000).

321. *Id.* § 107 (2000).

322. *Id.*

323. *See, e.g.*, Campbell v. Acuff-Rose Music, Inc., 510 U.S. 569, 578–81 (1994) (acknowledging the strong public interest in critical works such as parody); Sony Corp. of Am. v. Universal City Studios, 464 U.S. 417, 428–34 (1984) (interpreting the concept of fair use broadly because of the public interests at stake).

324. 17 U.S.C. § 107.

325. I am using the term "productive use" much more liberally than the dissent in *Sony*. *See Sony*, 464 U.S. at 477–81 (Blackmun, J. dissenting).

structure resources for which access is sustained involve the production of public and nonmarket goods that generate positive externalities realized by society as a whole.

First and foremost, fair use facilitates the creative process itself—the transformative manipulation and modification of existing works (nonrival inputs) to produce new creative works (public good outputs) that have the potential to generate positive externalities.[326] Less often acknowledged but perhaps of equal importance, the fair use doctrine facilitates experimentation and learning, intellectual processes that generate direct benefits to participants as well as diffuse external benefits for society.[327]

There is some degree of sensitivity in both patent and copyright law for sustaining open access to intellectual infrastructure, as exhibited by the idea-expression doctrine and the nonpatentability of abstract ideas.[328] In this brief discussion, I have ignored the growth in intellectual property protection in recent decades, as well as the ongoing debate over the optimal design of intellectual property rights, and whether the information commons is at risk of enclosure.[329] In a separate article, I explore these issues and argue that institutions, such as intellectual property, ought to respond explicitly to the fact that certain intellectual resources are infrastructure.[330]

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326. *See* Lydia P. Loren, *Redefining the Market Failure Approach to Fair Use in an Era of Copyright Permission Systems*, 5 J. INTELL. PROP. L. 1, 49 (1997) ("An examination of the[ ] enumerated uses reveals a common thread: each one of these uses provides external societal benefits far beyond the benefits to the individual who is making the criticism, the comment, the news report or the individual who is doing the teaching, the scholarship or the research."); *see also* Cohen, *Perfect Curve*, *supra* note 47, at 1803–04 (explaining that the traditional economic analysis of the supply and demand curves for copyrighted information views consumer surplus as benefits derived from consumption and not productive use); Lemley, *The Economics of Improvement*, *supra* note 105, at 1056–58.

327. *See* sources cited *supra* note 326.

328. *See* 17 U.S.C. § 102(b) ("In no case does copyright protection for an original work of authorship extend to any idea, procedure, process, system, method of operation, concept, principle, or discovery . . . ."); Diamond v. Chakrabarty, 447 U.S. 303, 309 (1980) ("The laws of nature, physical phenomena, and abstract ideas have been held not patentable.").

329. Two recent books by Landes and Posner provide a nice point of entry into the voluminous literature on these issues. *See* LANDES & POSNER, ECONOMIC STRUCTURE, *supra* note 285; LANDES & POSNER, POLITICAL ECONOMY, *supra* note 68.

330. Frischmann, Intellectual Infrastructure, *supra* note 283.

IV. UNDERSTANDING THE SOCIAL VALUE OF AN OPEN INTERNET INFRASTRUCTURE AND THE IMPLICATIONS FOR THE NETWORK NEUTRALITY DEBATE

This final Part demonstrates how infrastructure theory applies to the Internet in the context of the particularly contentious open access versus private control debate over network neutrality. At the heart of this debate is whether the Internet should retain its end-to-end architecture and continue to be managed in an openly accessible manner. Ultimately, the outcome of this debate will determine whether the Internet continues to operate as a mixed infrastructure (commercial, public, and social), or whether it evolves into a commercial infrastructure optimized for the production and delivery of commercial outputs.[331] As Lessig reminded us in *The Future of Ideas*, there are "two futures in front of us."[332]

331. In his most recent book, *Free Culture: How Big Media Uses Technology and the Law To Lock Down Culture and Control Creativity*, Lessig is concerned with "the troubles the Internet causes even after the modem is turned off." LESSIG, FREE CULTURE, *supra* note 68, at xiii–xiv. Lessig considers the two meta processes by which culture is produced—an open, free creative process and a controlled, permission-first process—and argues that the law is changing to support the latter at the expense of the former. *Id.* at xiv. Although Lessig focuses on a different infrastructure than I—specifically, the law—we are concerned with the same dynamic: the optimization of infrastructure for a certain range of (commercial) outputs.

332. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 7; Benkler, *From Consumers to Users*, *supra* note 14, at 563–65 (making a similar point); Jack Balkin, *Digital Speech and Democratic Culture: A Theory of Freedom of Expression for the Information Society*, 79 N.Y.U. L. REV. 1, 19–23 (2004) (same). Lessig, Benkler, and Balkin vividly paint the picture of what the Internet would look like as a pure commercial infrastructure; each sees possibility of the Internet *optimized* to deliver content-on-demand. LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 7; Benkler, *From Consumers to Users*, *supra* note 14, at 576–79; Balkin, *supra*, at 20–21 (describing a digital environment in which "access providers seek to cocoon their customers" and broadband companies enclose not only their proprietary content (and that of their affiliates) but also the "end-user's Internet experience" itself). Lessig paints a less vivid picture of the Internet as mixed commercial, public and social infrastructure because, as he notes, "the very premise of the Internet is that no one can predict how it will develop." LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 7. Still, Lessig illustrates his vision with detailed descriptions of the Internet's creative enterprises, its technologies that enable users to engage more fully in the creative process, and its ability to enhance community and cultural values. *Id.* at 7–10; *see also* LESSIG, FREE CULTURE, *supra* note 68, at 7–8 (providing a similarly dichotomous picture of culture). Balkin has a similar vision of the Internet as Lessig, although he is focused on the social value of promoting a democratic culture through the principle of free speech. *See* Balkin, *supra*, *passim*; *see also infra* notes 383–402 and accompanying text (relating Balkin's free speech theory with infrastructure theory).

A. THE INTERNET AS INFRASTRUCTURE

The Internet consists of many infrastructure resources. Scholars have delineated two macro-level infrastructure resources. The *physical infrastructure* consists of a wide variety of physical networks interconnected with each other, while the *logical infrastructure* consists of the standards and protocols that facilitate seamless transmission of data across different types of physical networks.[333] The physical and logical infrastructure both act as essential inputs into downstream production of applications and content.[334] In contrast with the upstream-downstream/input-output model used in this Article, Internet scholars tend to focus on layered models of the Internet that distinguish between complementary layers based on the functions each layer performs.[335] The number of layers in particular models varies, but the following four-layered model in table 4 is sufficient for our purposes. As the structure of this model implies, the physical and logical infrastructure are the foundational layers upon which the Internet environment we experience has been built. Thus, for purposes of this Article (and ease of reference), I refer to the physical and logical infrastructure together as either the "Internet" or the "Internet infrastructure" and to the applications and content as "downstream outputs."[336]

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333. *See, e.g.*, Benkler, *From Consumers to Users*, *supra* note 14, at 570–72.

334. *See* Frischmann, *Internet Infrastructure*, *supra* note 42, at 34–41 (modeling the "extrinsic" aspects of the Internet infrastructure). Some applications are simply content delivery mechanisms while others combine content delivery with content creation. While there is a considerable amount of content for which the Internet is not an "essential" input to production (e.g., music), the Internet is an "essential" input for a wide variety of applications that significantly lower the cost of distributing such content (e.g., peer-to-peer software, e-mail, instant messaging, chat rooms, the World Wide Web). Further, as discussed below, there is a considerable amount of content for which the Internet is an "essential" input to production (e.g., blogs, Web pages, peer and consumer annotated books). On the last example, see http://free-culture.cc/remixes/.

335. *See, e.g.*, Benkler, *From Consumers to Users*, *supra* note 14; Farrell & Weiser, *supra* note 6, at 90–91; Douglas C. Sicker & Joshua L. Mindel, *Refinements of a Layered Model for Telecommunications Policy*, 1 J. ON TELECOMM. & HIGH TECH. L 69 (2002); Kevin Werbach, *A Layered Model for Internet Policy*, 1 J. ON TELECOMM. & HIGH TECH. L. 37, 57–64 (2002); Christopher S. Yoo, *Would Mandating Broadband Network Neutrality Help or Hurt Competition? A Comment on the End-to-End Debate*, 3 J. ON TELECOMM. & HIGH TECH. L. 32–34 (2004) [hereinafter Yoo, *Mandating Broadband Network Neutrality?*].

336. Many of these downstream outputs also may constitute infrastructure

Table 4: Four-Layered Model of the Internet

Layer	Description	Examples
Content	Information/data conveyed to end-users	E-mail communication, music, Web page
Applications	Programs and functions used by end-users	E-mail program, media player, Web browser
Logical Infrastructure	Standards and protocols that facilitate transmission of data across physical networks	TCP/IP, domain name system
Physical Infrastructure	Physical hardware that comprise interconnected networks	Telecommunications, cable and satellite networks, routers and servers, backbone networks

The Internet meets all three demand-side criteria for infrastructure. The Internet infrastructure is a partially (non)rival good; it is consumed both nonrivalrously and rivalrously, depending upon available capacity.[337] The benefits of the Internet are realized at the ends. Like a road system, a lake, and basic research, the Internet is socially valuable primarily because of the productive activity it facilitates downstream. That is, end-users hooked up to the Internet infrastructure generate value and realize benefits through the applications run on their computers and through the consumption of content delivered over the Internet. End-users thus create demand for Internet infrastructure through their demand for applications and content.

The Internet currently is a mixed commercial, public, and social infrastructure. As described below, the Internet is per-

(e.g., a Web browser). I will not, however, focus on them in this Article.

337. *See* Frischmann, *Internet Infrastructure*, *supra* note 42, at 24–34 (modeling the "intrinsic" aspects of the Internet infrastructure). To be more precise, the physical infrastructure and certain components of the logical infrastructure such as the domain name system are partially (non)rival insofar that (1) the risk of congestion depends upon the amount of capacity, number of users, and other contextual factors, and (2) this risk can be managed in a fashion that sustains nonrivalry in consumption. *See supra* Part II.A.

haps the clearest example of an infrastructure resource that enables the production of a wide variety of public, private, and nonmarket goods, many of which are network goods.[338]

Like most traditional infrastructure, the Internet currently is managed in an openly accessible manner.[339] The current Internet infrastructure evolved with the "end-to-end" design principle as its central tenet.[340] This design principle is implemented in the logical infrastructure of the Internet through the adoption of standardized communication protocols (e.g., the Internet Protocol suite).[341] End-to-end essentially means that infrastructure providers cannot differentiate or discriminate among data packets carried by their networks.[342] This design promotes the open interconnection of networks and focuses application development and innovation on the demands of end-users.[343] For the most part, infrastructure providers are ignorant of the identity of the end-users and end-uses, and at the same time, end-users and end-uses are ignorant of the various networks that transport data packets.[344] In a sense, shared ignorance is "built" into the infrastructure and precludes individualized exclusion of end-users or end-uses.[345]

The institution that sustains the Internet infrastructure commons rests upon social norms embodied in the widespread adoption of technical standards, which are subject to change.[346] In fact, there is considerable pressure for change, pressure to replace the existing "dumb," open architecture with an "intelligent," restrictive architecture capable of differentiating (and discriminating) among end-uses and end-users. Pressure for change derives from many sources: the Internet's evolution to broadband infrastructure, applications, and content; the rapid

338. *See infra* Part IV.B.3.

339. LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 39 (noting that both the Internet and roads are "end-to-end systems" and that both could be "smart").

340. *Id.* at 34–35; Frischmann, *Internet Infrastructure, supra* note 42, at 33.

341. *See* Farrell & Weiser, *supra* note 6, at 91 (describing how the Internet Protocol implements the end-to-end architecture).

342. Mark A. Lemley & Lawrence Lessig, *The End of End-to-End: Preserving the Architecture of the Internet in the Broadband Era*, 48 UCLA L. REV. 925, 931 (2001).

343. *See id.*

344. Frischmann, *Internet Infrastructure, supra* note 42, at 27.

345. *Id.*

346. Lemley & Lessig, *supra* note 342, at 971.

increase in users; demand for latency-sensitive applications such as video-on-demand and IP telephony; demand for security measures and spam regulation measures implemented at the "core" of the Internet; and, more generally and importantly, demand for increased returns on infrastructure investments.[347] We should resist this pressure and think more carefully about the benefits of sustaining an Internet infrastructure commons.

B. THE NETWORK NEUTRALITY DEBATE AND THE FUTURE OF END-TO-END ARCHITECTURE

For the past two decades, academics, commercial entities, technologists, government officials, universities, and citizens have debated the future of the Internet infrastructure.[348] In the mid-1980s, participants in such debates focused on technology and coordinating interconnection among different types of networks.[349] In the late-1980s and early-1990s, attention shifted in part to the viability of privatization and commercialization.[350] Since 1995, when the privatization and commercialization

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347. *See* Odlyzko, *supra* note 29, at 324 (noting that the concern is really about the feasibility of price discrimination); Bruce M. Owen & Gregory L. Rosston, Local Broadband Access: *Primum Non Nocere* or *Primum Processi*? A Property Rights Approach 21–22 (July 2003) (Stanford Law School, John M. Olin Program in Law and Economics, Working Paper 263) (suggesting that the Internet's end-to-end architecture has stifled investment in broadband infrastructure and applications and thus slowed broadband deployment), *at* http://papers.ssrn.com/paper.taf?abstract_id=431620; *see also* Frischmann, *Internet Infrastructure*, *supra* note 42, at 8–9, 12–13, 15, 18 (explaining how "the recurring need for expensive infrastructure upgrades in response to congestion problems created a demand for investment dollars that tested the bounds of public funding and gradually led to increased reliance on private funds").

348. These debates are extensively covered elsewhere and will not be recounted here. *See generally* JANET ABBATE, INVENTING THE INTERNET 181–220 (1999).

349. *See id.*; Frischmann, *Internet Infrastructure*, *supra* note 42, at 12–15.

350. ABBATE, *supra* note 348, at 195–200; Brian Kahin, Commercialization of the Internet: Summary Report, RFC 1192 (Nov. 1990), *available at* http://www.faqs.org/rfcs/rfc1192.html; Jay P. Kesan & Rajiv C. Shah, *Fool Us Once Shame on You—Fool Us Twice Shame on Us: What We Can Learn from the Privatizations of the Internet Backbone Network and the Domain Name System*, 79 WASH. U. L.Q. 89, 130–43 (2001); *see also* Frischmann, *Internet Infrastructure*, *supra* note 42, at 15–20 & n.64 ("In the early 1990s, there was a significant discussion among interested parties in government, academia, industry, and the not-for-profit sector concerning privatization and commercialization.").

process was more or less complete, attention again has shifted to governance and (de)regulation.[351]

The degree to which infrastructure providers (i.e., network owners) should have control over their privately owned networks has received considerable attention.[352] Essentially, the open access versus control debate involves the same set of economic issues discussed in previous parts with respect to traditional infrastructure, environmental resources, and informational resources. A substantial literature approaches this debate from a variety of perspectives, including law,[353] economics,[354] and technology.[355] I believe the current debate is skewed, however, because it focuses myopically on neutrality, market-driven provision of commercial outputs, and innovation. A new approach is needed because there is much more at stake than the current debate reflects.

1. Network "Neutrality"

Professor Tim Wu recently summarized the current status of the ongoing open access versus control debate and couched it as one about "network neutrality," that is, whether the Internet should be made *neutral* (and if so, how).[356] Wu and Lessig sub-

351. *See, e.g.*, Tim Wu, *The Broadband Debate: A User's Guide*, 3 J. ON TELECOMM. & HIGH TECH. L. 69, 75–79 (2004) [hereinafter Wu, *The Broadband Debate*]; Michael K. Powell, *Preserving Internet Freedom: Guiding Principles for the Industry*, 3 J. ON TELECOMM. & HIGH TECH. L. 5 (2004).

352. In the context of emerging broadband infrastructure, the open access debate focuses on the vertical relationships between input and output producers primarily from a competition policy perspective. For an excellent treatment of these issues, see Farrell & Weiser, *supra* note 6. In this context, open access "generally refers to a structural requirement that would prevent broadband operators from bundling broadband service with Internet access from in-house Internet service providers." Tim Wu, *Network Neutrality, Broadband Discrimination*, 2 J. ON TELECOMM. & HIGH TECH. L. 141, 147–48 (2003).

353. *See, e.g.*, Lemley & Lessig, *supra* note 342; James B. Speta, *Handicapping the Race for the Last Mile? A Critique of Open Access Rules for Broadband Platforms*, 17 YALE J. ON REG. 39, 77–78 (2000); Phil Weiser, *Paradigm Changes in Telecommunications Regulation*, 71 U. COLO. L. REV. 819 (2000); Glenn A. Woroch, *Open Access Rules and the Broadband Race*, 2002 MICH. ST. DCL L. REV. 719.

354. *See, e.g.*, Owen & Rosston, *supra* note 347; Paul A. David, *The Evolving Accidental Information Super-Highway*, 17 OXFORD REV. ECON. POL'Y 158 (2001). In some respects, the approach taken in this Part follows David's lead.

355. *See, e.g.*, Marjory S. Blumenthal & David D. Clark, *Rethinking the Design of the Internet: The End to End Arguments vs. the Brave New World*, 1 ACM TRANSACTIONS ON INTERNET TECH. 70 (2001).

356. *See* Wu, *Network Neutrality, Broadband Discrimination*, *supra* note 352, at 145–49; Wu, *The Broadband Debate*, *supra* note 351, at 88–94.

mitted an ex parte letter to the Federal Communications Commission (FCC) explaining their view that network neutrality ought to be an "aspiration" of the FCC.[357] Wu's research provides a fair assessment of the current debate, and I accordingly use his work to illustrate how the infrastructure theory reveals demand-side issues that have not been adequately addressed in the current debate. While the network neutrality debate encompasses many policy issues, I focus exclusively on the future of the end-to-end architecture of the Internet.

How does the end-to-end design principle relate to network neutrality? Initially, implementing a commons via end-to-end network design might appear "neutral" to applications while shifting to an "intelligent" network design capable of allocating access to the infrastructure based on the identity of the uses (users) appears "nonneutral." The problem with this view is that neutrality is a "finicky" concept.[358] As Wu explained:

> As the universe of applications has grown, the original conception of IP neutrality has dated: for IP was only neutral among data applications. Internet networks tend to favor, as a class, applications insensitive to latency (delay) or jitter (signal distortion). Consider that it doesn't matter much whether an email arrives now or a few milliseconds later. But it certainly matters for applications that want to carry voice or video. In a universe of applications that includes both latency-sensitive and insensitive applications, it is difficult to regard the IP suite as truly neutral as among all applications.
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> . . . The technical reason IP favors data applications is that it lacks any universal mechanism to offer a quality of service (QoS) guarantee. It doesn't insist that data arrive at any time or place. Instead, IP generally adopts a "best-effort" approach[.] . . . [A]s a consequence, it implicitly disfavors applications that do care.[359]

Wu and others are correct to say that the end-to-end design precludes differentiated QoS[360] and thus disfavors latency-sensitive applications, such as IP telephony and video-on-demand.[361] To be sure, this may be one significant cost of sus-

357. Letter from Timothy Wu, Associate Professor, University of Virginia School of Law, & Lawrence Lessig, Professor of Law, Stanford Law School, to Marlene H. Dortch, Secretary, FCC 3 n.3 (Aug. 22, 2003), *available at* http://faculty.virginia.edu/timwu/wu_lessig_fcc.pdf.

358. Wu, *Network Neutrality, Broadband Discrimination*, *supra* note 352, at 147.

359. *Id.* at 148 (footnotes omitted).

360. The Internet currently provides best effort data delivery, which is a simple form of QoS. *See id.* at 148. There are different types of QoS, some of which are "more consistent" with end-to-end than others. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 47.

361. *See* Wu, *Network Neutrality, Broadband Discrimination*, *supra* note

taining an infrastructure commons.[362] Further, proponents of an intelligent Internet argue that the end-to-end design of the Internet inhibits other socially valuable applications best executed at the core rather than at the ends—security and spam regulation measures, for example.[363] While the relative effectiveness and costliness of executing various functions at the core or at the ends is a subject of debate, this also may be one significant cost of sustaining an infrastructure commons.

That end-to-end design favors one set of applications does not mean that shifting to QoS will not do the same. There is a significant risk that the inherent biases of the market mechanism will surface if access to the Internet infrastructure is allocated to users by private property owners employing fine-grained (end-user or end-use-specific) QoS.

Just as the current end-to-end design favors data applications at the expense of time-sensitive applications, shifting to a fine-grained QoS regime also may exhibit a bias for particular applications, specifically for commercial applications that generate observable and appropriable returns. The bias would not be technologically determined (as in the case of end-to-end design), but rather would be determined by the predictable operation of the market mechanism. As discussed above, given the ability to discriminate among end-users and end-uses on a packet-by-packet basis and the inability to perfectly price discriminate, infrastructure suppliers may bias access priority (via imperfect price discrimination) and/or optimize infrastructure design in favor of output markets that generate the highest levels of appropriable returns (producer surplus), at the expense of output markets that generate a larger aggregate surplus (direct consumer surplus, producer surplus, and external surplus).[364]

End-to-end design sustains a commons by insulating end-users from market-driven control over access.[365] Because infra-

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352, at 148; Yoo, *Mandating Broadband Network Neutrality?*, *supra* note 335, at 27–28, 30–31.

362. LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 46 (acknowledging this as a cost of sustaining a commons).

363. *See* Blumenthal & Clark, *supra* note 355; David, *supra* note 354, at 171–78; Yoo, *Mandating Broadband Network Neutrality?*, *supra* note 335, at 27–28, 31–41.

364. *See supra* Parts II.B–D, III.A (explaining the inherent bias of the market for observable and appropriable returns). Note that I leave aside concerns over anticompetitive behavior.

365. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 46. For discussion

structure providers cannot distinguish between end-uses or end-users, they cannot base access decisions or pricing on such information, nor can they optimize the infrastructure for a particular class of end-uses or end-users.

2. Commercial Outputs and Innovation

Discussion of the costs and benefits of preserving the end-to-end design of the Internet focuses on issues relevant to commercial infrastructure, specifically, on competition in upstream and downstream markets,[366] and on competition in innovation markets.[367] For example, Lessig, a major proponent of sustaining the end-to-end design, focuses extensively on the notion of sustaining an *innovation commons*. Lessig finds that experimenting, tinkering, and creating new applications and content are critically productive activities facilitated by the end-to-end architecture of the Internet.[368] Lessig is correct, but he could and should go much further.

Innovation is an integral part of the debate, but it ought not be the linchpin upon which end-to-end architecture of the Internet hangs.[369] Innovation is too narrow conceptually because of its traditional economic connection with the competi-

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of this point more generally, see *supra* Part II.D.

366. *See, e.g.*, Farrell & Weiser, *supra* note 6, at 123 (focusing on sustaining competition in upstream and downstream markets); Owen & Rosston, *supra* note 347, at 17–25 (focusing on commercial markets and arguing that a property rights approach is preferable to common carrier-type regulation); Yoo, *Mandating Broadband Network Neutrality?*, *supra* note 335, at 31–41 (framing the network neutrality debate in competition theory); *cf.* Manheim & Solum, *supra* note 100 (analyzing root service, a fundamental component of the domain name system's operation, as a private good that could be provided efficiently by a competitive market).

367. *See* Wu, *Network Neutrality, Broadband Discrimination*, *supra* note 352, at 152–54; Wu, *The Broadband Debate*, *supra* note 351, at 80–84; Letter from Wu and Lessig to FCC, *supra* note 357, at 5–7.

368. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 40–41.

369. Yet this seems to be the case. Both sides seem to agree that innovation is the objective and debate what type of management regime will best promote innovation. *Cf.* Wu, *The Broadband Debate*, *supra* note 351, at 80 ("[T]he greatest unifying belief as between the Openist and Deregulationist is a common idolization of innovation."). Arguably, innovation has become the focus of the debate because it is the only—or at least, the primary—argument raised by Openists for maintaining the end-to-end architecture of the Internet. This is unfortunate because many of the applications that are truly valuable to society are not all that innovative (or creative)—at least, not anymore—and are not subject to continued improvement. Consider, for example, e-mail, chat rooms, and message boards.

tive process and commercial markets.[370] As discussed in the next section, the Internet supports a substantially wider range of socially valuable downstream activities that are neither innovative nor commercial.[371]

The problem with focusing on innovation is that it pushes the debate into the confines of competition theory.[372] For example, Wu argues that network neutrality ought to be accepted both by openists and deregulationists as the operative normative goal, basing his views on the Schumpeterian concept that

370. I recognize that Lessig uses "innovation" broadly to mean "[n]ot just the innovation of Internet entrepreneurs . . . , but also the innovation of authors or artists more generally." LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 6; *see also id.* at 10 ("Though most distinguish innovation from creativity, or creativity from commerce, I do not."); *id.* at 19 ("This book is fundamentally about the Internet and its effect on innovation, *both commercial and non.*") (emphasis added). The problem with this approach is that innovation generally is considered to be intimately connected with commercialization. That is, from a definitional standpoint, innovation is not simply the creation of something new and valuable, but rather it is the creation of something new and commercializable. *See* F.M. SCHERER, INNOVATION AND GROWTH: SCHUMPETERIAN PERSPECTIVES 8 (1984). I should note that I also made the mistake of using a broad notion of innovation in another article. *See* Frischmann, *Innovation and Institutions*, *supra* note 33, at 348–49 (criticizing the link to commercialization and adopting a broader definition). In *The Future of Ideas*, Lessig emphasizes that he is concerned with innovation *and* creativity. LESSIG, THE FUTURE OF IDEAS, *supra* note 7, *passim*. While I fear that participants in the network neutrality debate tend to focus on innovation, I believe that creativity is also too narrow a concept because it fails to capture the full range of socially valuable productive activity which the Internet makes possible. *See infra* Part IV.B.3; *see also* Frischmann, *Internet Infrastructure*, *supra* note 42, at 68–69. As I have noted previously:

> "[t]he Internet is like an overloaded highway that needs to be upgraded. But if done badly, the Internet's ability to support innovative, as-yet unimagined applications could be in jeopardy." While we certainly should be concerned with the fate of "unimagined applications," the same rationale applies with even greater force to the fate of many existing public goods applications that thrive on the Internet.

Id. (quoting *Upgrading the Internet*, ECONOMIST (TECH.Q.), Mar. 24, 2001, at 32, 32).

371. Lessig knows this and clearly intends to use innovation broadly. *See supra* note 370.

372. For a thorough, competition-oriented analysis in this area, see Farrell & Weiser, *supra* note 6, at 86–134; *see also* Weiser, *supra* note 213, at 74–84 (advocating an "antitrust-like approach to regulation"). Farrell and Weiser analyze whether infrastructure "providers can be trusted to allow open access when it is efficient to do so." Farrell & Weiser, *supra* note 6, at 96. Their central analytical tool is the economic concept of "internalizing complementary externalities," which suggests that firms will manage their resources openly when doing so "enhances consumer value." *Id.* They explore this concept and its eight important limitations. *Id.* at 105–19. Farrell and Weiser do not, however, explore the demand-side problems highlighted in this Article.

innovation is an essential part of an evolutionary competitive process.[373] Incidentally, Wu and Lessig make the same argument in their letter to the FCC.[374] From the Schumpeterian perspective, innovation is about the creation and distribution of new commercial outputs that will drive competition with incumbents, a process Schumpeter famously referred to as "creative destruction."[375] Wu suggests that a neutral Internet will support "meritocratic" competition among all applications (new and old),[376] fostering "a Darwinian competition among every conceivable use of the Internet so that only the best survive."[377] This view leaves unanswered important questions: By what process will such competition take place? On what metric do we assess what constitutes the "best" uses?[378] Presumably, Wu, like Schumpeter, expects that competitive markets will effectively judge the merits of innovative applications on the basis of consumer demand (consumers' willingness to pay). This perspective is problematic because market competition judges the merit of outputs on the basis of observable and appropriable returns rather than on overall social welfare.[379]

To be fair, Wu does not expressly define meritocratic competition and thus does not define such competition as market-driven competition. I presume he means market-driven competition because of his emphasis on Schumpeter and innova-

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373. In his first article, Tim Wu makes an abbreviated and admittedly simple case for network neutrality based on the Schumpeterian view that innovation is an evolutionary process, and proceeds to analyze institutional means more or less under the assumption that network neutrality is the normative goal. Wu, *Network Neutrality, Broadband Discrimination*, *supra* note 352, at 191–96, 197. In his second article, he spells out in more detail why network neutrality ought to be accepted both by Openists and Deregulationists as the operative normative goal. *See* Wu, *The Broadband Debate*, *supra* note 351, at 84.

374. *See* Letter from Wu and Lessig to FCC, *supra* note 357, at 5–8 (arguing that network neutrality is critical to sustaining an "evolutionary, or competitive model of innovation").

375. J.A. SCHUMPETER, CAPITALISM, SOCIALISM AND DEMOCRACY 81–87 (5th ed. 1976).

376. *See* Wu, *Network Neutrality, Broadband Discrimination*, *supra* note 352, at 144–46.

377. *Id.* at 142.

378. Will uses compete in the market for access to the infrastructure and consumers? Will survival depend upon consumers' willingness to pay for outputs and, in turn, on output producers' willingness to pay for access to the infrastructure?

379. *See supra* Parts II, III.

tion.[380] The Schumpeterian evolutionary perspective yields important insights that are relevant to the analysis of infrastructure resources. For example, as noted earlier with respect to lakes and basic research,[381] and as Wu described:

> All of these teachings lead to a single principle that should be an absolute policy consensus. Lost-cost market entry is the common foundation of the innovation theories that both Deregulationists and Openists subscribe to. That means preventing any single actor, governmental or otherwise, from becoming lord of the technological future. A multiplicity of innovating actors, even if suffering from the same inability to accurately predict the future, may nonetheless stumble upon the optimal path.[382]

The point Wu makes can and should be extended beyond the context of innovation, with its focus on commercial competition, to infrastructure more generally.

To be clear, competition in upstream and downstream markets and innovation are important and deserve careful attention. Further, I agree with Wu, Lessig, and others regarding the significant benefits that a theoretically neutral system has for innovation from an evolutionary perspective. I do not think, however, that true neutrality is attainable, nor do I believe that the Internet is a system focused on facilitating innovation alone.

3. The Internet as Commercial, Public, and Social Infrastructure

The Internet is a mixed commercial, public, and social infrastructure.[383] The public and social aspects of the Internet in-

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380. *See* Wu, *The Broadband Debate, supra* note 351, at 80–84.

381. *See supra* Part III.

382. Wu, *The Broadband Debate, supra* note 351, at 84.

383. Like a cable system, the Internet is a commercial infrastructure because it is an input into the delivery of a wide range of controlled digital media content for consumption. The delivery of controlled (or use-restricted) digital content purely for end-user consumption can be classified as a private good; the content provider is using the infrastructure to provide a service to the consumer (delivery of content for consumption) under conditions that render the output private (rivalrous and excludable). The Internet also acts as an input into a number of commercial processes that have public good components and some potential for positive externalities. Consider, for example, use of the Internet for information dissemination and exchange for advertising, marketing, and to facilitate business transactions, as well as information gathering for product development, consumer demand assessment, and operations management. *See* ROBERT E. LITAN & ALICE M. RIVLIN, BEYOND THE DOT.COMS: THE ECONOMIC PROMISE OF THE INTERNET 4–5, 19–38 (2001). These processes are likely to be strictly tailored to channeling end-users toward purchasing

frastructure are largely undervalued in the current debate. Bringing these aspects of the Internet into focus strengthens the case for preserving the end-to-end architecture of the Internet. In other words, the demand-side nature of the infrastructure theory supports an additional, strong argument in favor of open access. Ultimately, sustaining an Internet infrastructure commons avoids relying on either the government or the market to pick winners (or survivors) among downstream producers of private, public, and nonmarket goods.[384]

What makes the Internet valuable to *society*?[385] It is very difficult to estimate the full social value of the Internet, in large part because of the wide variety of downstream uses that generate public and nonmarket goods. Despite such difficulty, we know that the Internet is "[t]ransforming [o]ur [s]ociety."[386] The transformation is similar to transformations experienced in the past with other infrastructure,[387] yet now change is occuring in a more rapid, widespread, and dramatic fashion.[388]

The Internet environment is quickly permeating all aspects of the lives, affairs, and relationships of individuals, companies, universities, organizations, and governments worldwide. It is having significant effects on fundamental social processes and resource systems that generate value for society. The Internet is transforming commerce, community, culture, education, government, health, politics, and science—all information- and communications-intensive systems. The transformation is taking place at the ends, where people are empowered to participate and are engaged in socially valuable, productive activities. As Jack Balkin has observed, the "digital revolution makes

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and consuming commercial content. *See* Balkin, *supra* note 332, at 14.

384. *See supra* Part II.D.

385. I ask my Cyberlaw students this question each semester. While the range of answers that my students provide always proves to include a few surprises (usually for me, sometimes for the whole class), most students emphasize general purpose communications applications, such as e-mail and instant messaging, the World Wide Web, and file sharing.

386. INVESTING IN OUR FUTURE, *supra* note 1, at 11–20.

387. *Id.* at 11.

388. *Id.* ("As we approach the new millennium, it is clear that the 'information infrastructure'—the interconnected networks of computers, devices, and software—may have a greater impact on worldwide social and economic structures than all networks that have preceded them."); *id.* at 35 ("Within the next two decades, the Internet will have penetrated more deeply into our society than the telephone, radio, television, transportation, and electric power distribution networks have today. For many of us, the Internet has already become an integral part of our daily lives.").

possible widespread cultural participation and interaction that previously could not have existed on the same scale."[389]

The Internet opens the door widely for users, and, more importantly, it opens the door to many different activities that are productive. End-users actively participate in the Internet: they engage in innovation and creation;[390] they speak about anything and everything;[391] they maintain family connections and friendships; they debate, comment, and engage in political and nonpolitical discourse; they meet new people; they search, research, learn, and educate; and they build and sustain communities.[392]

These are the types of productive activities that generate substantial social value, value that too easily evades observation or consideration within conventional economic transactions.[393] When engaged in these activities, end-users are not passively consuming content delivered to them, nor are they producing content solely for controlled distribution on a pay-to-consume basis.[394] Instead, end-users interact with each other to build, develop, produce, and distribute public and nonmarket goods.[395] Public participation in such activities results in exter-

389. Balkin, *supra* note 332, at 3. In this article, Balkin proposes a theory of free speech that casts free speech as the means to promoting a democratic culture. He defines "democratic culture" to be "a culture in which individuals have a fair opportunity to participate in the forms of meaning-making that constitute them as individuals." *Id.* at 3. I believe his arguments for free speech parallel my own economic arguments which push for openly accessible management of some public and social infrastructure, including the Internet.

390. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 120–34; Balkin, *supra* note 332, at 33–34.

391. Balkin, *supra* note 332, at 33. "[S]peech on the Internet ranges over every possible subject and mode of expression, including the serious, the frivolous, the gossipy, the erotic, the scatological, and the profound. The Internet reflects popular tastes, popular culture, and popular enthusiasms." *Id.*

392. *See id.* at 40–44.

393. *See* LITAN & RIVLIN, *supra* note 383, at 5 (noting that "[n]ot all of the economic benefits of the Internet will show up in productivity statistics" and suggesting that "these hard-to-quantify benefits . . . are important even if they never enter the measured output of the economy"); *see also id.* at 45–63 (finding that some "benefits of the Internet that may not show up in the GDP").

394. I prefer pay-to-consume over pay-per-use because I have yet to see a pay-per-use system where the purchaser is allowed to use the work productively.

395. Balkin sees this process as follows:

> Internet speech is participatory and interactive. People don't merely watch (or listen to) the Internet as if it were television or radio. Rather, they surf through it, they program on it, they publish to it, they write comments and continually add things to it. Internet speech

nal benefits that accrue to society as a whole (online and offline) that are not captured or necessarily even appreciated by the participants.

Further, active participation in these activities by some portion of society benefits even those who do not participate. In other words, the social benefits of Internet-based innovation, creativity, cultural production, education, political discourse and so on are not confined to those who use the Internet; the social benefits spill over. For example, when bloggers[396] engage in a heated discussion about the merits of proposed legislation or the Iraq war, citizens who never use the Internet benefit because others have deliberated. With respect to weblogs, in particular, political scientists, journalists, economists, and lawyers, among others, are beginning to appreciate and more carefully study the dynamic relationships between this new medium of communication and traditional, offline modes of communication and social interaction (whether economic, political, social, or otherwise).[397]

Consider the fact that a significant portion of the content traveling on the Internet is noncommercial, speech-oriented information—whether personal e-mails and Web pages, blog postings, instant messaging, or government documentation[398]—and the economic fact that such information is a pure public good generally available for both consumption and productive use by

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> is a social activity that involves exchange, give and take. The roles of reader and writer, producer and consumer of information are blurred and often effectively merge.

Balkin, *supra* note 332, at 34.

396. For a concise background on weblogs, see Daniel W. Drezner & Henry Farrell, The Power and Politics of Blogs (July 2004) (presentation at the 2004 American Political Science Association Annual Meeting), http://www.utsc.utoronto.ca/~farrell/blogpaperfinal.pdf.

397. *See id.* (observing that "[w]eblogs occupy an increasingly important place in American politics" and studying "the distribution of readers across the array of blogs, and the interactions between significant blogs and traditional media outlets"); *see also* Caio M.S. Pereira Neto, *Online Collaboration Media and Political Economy of Information: A Case Study*, 21 J. MARSHALL J. COMPUTER & INFO. L. 511 (studying several collaborative media projects and comparing them with traditional media).

398. Consider, for example, the recent findings of the Pew Internet and American Life Project regarding online content creation and distribution. Forty-four percent of Internet users produce and distribute content and interact online. Productive activities range from posting (e.g., photographs) to engaging in interactive products (e.g., blogs). AMANDA LENHART ET AL., PEW INTERNET & AMERICAN LIFE PROJECT, CONTENT CREATION ONLINE 1 (2004), *available at* http://www.pewinternet.org/pdfs/PIP_Content_Creation_Report.pdf.

recipients. The productive use and reuse of such information creates benefits for the user, the downstream recipients, and even people that never consume or use the information. These benefits are positive externalities that are not fully appropriated or even appreciated by the initial output producer.

It is worth noting that welfare can be ratcheted up in incredibly small increments and still lead to significant social surplus. As participants educate themselves, interact, and socialize, for example, the magnitude of positive externalities may be quite small. Diffusion of small-scale positive externalities, however, can lead to a significant social surplus when the externality-producing activity is widespread, as it is on the Internet. This concept seems to reflect in economic terms the basic idea underlying Balkin's democratic culture theory.[399] This view also complements many of Benkler's arguments concerning the social value of diversity in both the types and sources of content.[400]

Widespread, interactive participation in the creation, molding, distribution, and preservation of culture,[401] in its many different forms and contexts, may be an ideal worth pursuing from an economic perspective because of the aggregate social welfare gains that accrue to society when its members are actively and productively engaged.[402] Balkin focuses on a theory of free speech as the means for pursuing this ideal; I focus on a

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399. *See* Balkin, *supra* note 332, at 33–45; *see also* Netanel, *supra* note 42, at 341–63 (developing a similar theory, although focused on copyright law as the relevant infrastructure).

400. *See generally* Yochai Benkler, *Siren Songs and Amish Children: Autonomy, Information, and Law*, 76 N.Y.U. L. REV. 23 (2001).

401. The Internet facilitates the archival of culture, history, and other types of information that may be quite valuable to future generations. *See* Deirdre K. Mulligan & Jason M. Schultz, *Neglecting the National Memory: How Copyright Term Extensions Compromise the Development of Digital Archives*, 4 J. APP. PRAC. & PROCESS 451, 465–70 (2002).

402. Society benefits in a number of ways. First, participation in these processes generates outputs (e.g., information) that society consumes. Second, participants in these processes benefit by virtue of their participation; they appreciate some immediate value (otherwise, why participate?) and they also develop communications skills and other knowledge. Third, to the extent that participation in these activities develops skills and knowledge, nonparticipants also benefit because of social interdependencies with these participants in the offline world. In other words, people that never use the Internet may be better off when members of their physical world community are more skilled and knowledgeable. I leave further consideration of the various ways in which participation in these processes generate externalities for future work.

complementary theory of an infrastructure commons as the means for pursuing the same.

4. Reframing the Network Neutrality Debate

The network neutrality debate is not really about neutrality per se; nor is it about innovation alone. The debate must broaden its focus from the merits of sustaining an *innovation commons* to the merits of sustaining an *infrastructure commons*—that is, of sustaining open, public access to infrastructure. The debate ought to be about optimizing the Internet for society as a whole and it ought to take into account the full range of interests at stake. This type of optimization problem raises the familiar issues and choices seen in other debates over *open access* or *restricted access*.[403] What type of infrastructure do we as a society desire? Do we prefer an Internet infrastructure managed in an openly accessible manner? Or, do we prefer an Internet infrastructure managed to maximize the profits of property owners? There are benefits and costs to both types of management regimes that need to be carefully evaluated and balanced.[404]

Presented with this difficult (but properly framed) optimization problem, the standard economic solution of (1) allowing the management of the infrastructure resources to shift to a market-driven, pricing-based system to meter traffic and facilitate recovery of returns on infrastructure investments, and (2) relying on the government to directly subsidize the producers of worthwhile public and nonmarket goods seems much less attractive. The prospect of so-called "government failure" at the second step (subsidization) looms large because the transaction costs of identifying, evaluating the merits of, and awarding subsidies to worthwhile end-user projects are likely tremendous, particularly given the wide range of productive activities undertaken on a small-scale basis by many different types of end-users. (The misallocation of resources would really be a failure of both government and market.) Managing the infrastructure in an openly accessible manner avoids government

403. *Cf.* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 37 (discussing neutrality and emphasizing that we must "see [end-to-end] design as a *choice*").

404. *See* David, *The Evolving Accidental Information Super-Highway*, *supra* note 354. For a visual representation of network neutrality balancing, see *infra* appendix figures 6 and 7.

and market failure but, like some traditional infrastructure, leaves some issues to be resolved.

In the context of the Internet, the viability of open access may depend (politically) on whether alternative means exist to address many of the concerns raised in opposition to open access principles. For instance, with respect to congestion, we might implement pricing systems based on timing rather than on content. Another possible solution is to regulate consumptive content from the ends, for example, by taxing or regulating spam.[405] Another important solution involves expanding capacity. This leads to the issue of incentives—how will we compensate infrastructure capacity producers? Some viable options include direct subsidization of infrastructure expansion, tax incentives to support the same, cooperative research and development projects, and joint ventures. Realization of the economic benefits of end-to-end as a sustainable infrastructure commons makes researching these alternatives all the more necessary.[406]

In the end, applying the infrastructure theory to this optimization problem neither solves the problem nor provides a de-

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405. This is actually a lesson to be learned from environmental law, where polluting uses of a resource are regulated in a manner that sustains open access for a wide range of other uses. *See supra* Part III.A.

406. A concrete example of a city recognizing the importance of widespread, public access to the Internet is the Philadelphia Wireless Project. *See* Bob Tedeschi, E-Commerce Report, *What Would Benjamin Franklin Say? Philadelphia Plans Citywide Free Wi-Fi Internet Access for Computer Users*, N.Y. TIMES, Sept. 27, 2004, at C8. The city government plans to deliver wireless broadband service to its citizens within the next two years. The wireless network would cover the city's entire 135 square mile area. The initial investment of the project would be $10 million dollars. The city hopes to offer this service for free. *Id.*

Philadelphia likens the Internet to traditional infrastructure such as the highway system, and recognizes that creating a city-wide wireless "hotspot" fosters commercial as well as public benefits for the city and its citizens. Specifically, the city hopes that small businesses and business travelers will commercially benefit from city-wide Internet access. In addition, the City of Philadelphia has acknowledged the nonappropriable social benefits and positive externalities attributable to widespread public access to the Internet. Such access may facilitate more efficient provision of city government services, better educational opportunities within school settings and more generally within the community, and the empowerment of disadvantaged individuals. *See id.* While some critics have argued that the market, and not city government, should provide Internet access to Philadelphia residents, the city's chief information officer, Diana Neff, has stated that "[t]he reason we won't just let the market do this is that there are societal needs that aren't inherently part of the capitalist system. We need to be sure no communities in Philadelphia are excluded, whether there's [a return on investment] or not." *Id.*

finitive answer to the tough choices that lie ahead. But the theory brings into focus the social value of sustaining an Internet infrastructure commons, and strongly suggests that the benefits of open access (costs of restricted access) are significantly greater than reflected in the current debate. Most importantly, infrastructure theory provides a better theoretical framework for understanding and evaluating "the *character of the* [Internet] and how it *relates to* [us as] *a community*."[407]

CONCLUSION

We live in an increasingly complex world with overlapping, interdependent resource systems that constitute our environment and affect our lives in significant, although sometimes subtle and complex, ways. These overlapping systems include not only natural resource systems but also human-made and socially constructed resource systems that constitute the world we live in and experience. It is critical that we, as a society, continually strive to better understand our environment so that we can appreciate, construct, and manage it as best we can. Too often, unfortunately, we take for granted the fundamental infrastructure resources upon which these systems depend.

The open access (commons) versus private control debate is really a battle over *our environment*—how it should be constituted, how it can be experienced, and how it will evolve. As the debate continues, it will become increasingly the subject of economic, political, and social conflict. Yet we barely understand the wide variety of interests at stake in these conflicts, and we rarely pause to seek a better understanding.

This Article devotes much needed attention to understanding how society benefits from infrastructure resources and how management decisions affect the wide variety of interests at stake. This Article links *infrastructure*, a particular set of resources defined in terms of the manner in which they create value, with *commons*, a resource management principle by which a resource is made openly accessible to all within a community regardless of their identity or intended use. As noted throughout this Article, the link implies a need to carefully evaluate the merits of openly accessible infrastructure in a context and with an awareness of the wide variety of interests at stake. This Article also develops a useful framework for evaluating the case for commons management, distinguishing

407. LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 21.

between *commercial, public, and social infrastructures* based on the manner in which value is created for and realized by society.

In a sense, infrastructure theory itself constitutes an infrastructure that can facilitate cross-disciplinary analysis of fundamental resources in a more comprehensive fashion. Infrastructure theory is applicable in a wide number of resource-focused disciplines and should serve as a platform for further research. Here are but a few possibilities:

Demand-side analysis of traditional infrastructure resources and nontraditional infrastructure resources. This Article focuses on a few examples of environmental, information, and Internet resources, but there is a wide range of resources deserving further demand-side analysis. Examples include the following: roads; communications networks; legal systems; lakes, the atmosphere, and other ecosystems; basic research; operating systems; and generic technology; Internet architecture; and the domain name system. These infrastructure resources generate value for society because of their fundamental role in complex, dynamic systems. A better understanding of these roles is critical to improving decision making regarding resource management.

Comparative analysis of legal and social institutions. Property rights, regulation, social norms, and other institutions sustain infrastructure resources in an openly accessible manner. There is considerable potential for cross-disciplinary institutional learning with respect to the means by which competing interests are reconciled. For example, as briefly noted in this Article, environmental law and intellectual property law sustain common resources through institutional means that combine property rights and regulation in very different ways. Further analysis of such institutions necessarily requires consideration of supply-side issues that have not been addressed in this Article.

Analysis of the interplay between infrastructure theory and antitrust law. Under certain market conditions, antitrust principles, such as the essential facilities doctrine, may require an input supplier to make the input openly accessible to output producers. Such principles generally involve an incomplete and under-theorized version of infrastructure theory. Interestingly, the essential facilities doctrine has been adopted in the European Union and elsewhere outside the United States at a time when the U.S. Supreme Court critically questioned its wisdom in a recent decision.[408]

Analysis of the implications of infrastructure theory to international development. Throughout the world, infrastructure resources provide the foundation upon which productive economies evolve. In the past thirty years, the manner in which infrastructures are provided to society has substantially changed in developing and developed countries. In the developing world, loans and aid may be conditioned upon a variety of infrastructure market reforms including privatization, industry restructuring, and (de)regulation. The theory advanced in this Article provides a useful perspective for distinguishing between commercial, public, and social infrastructure, and for evaluating such reform efforts.

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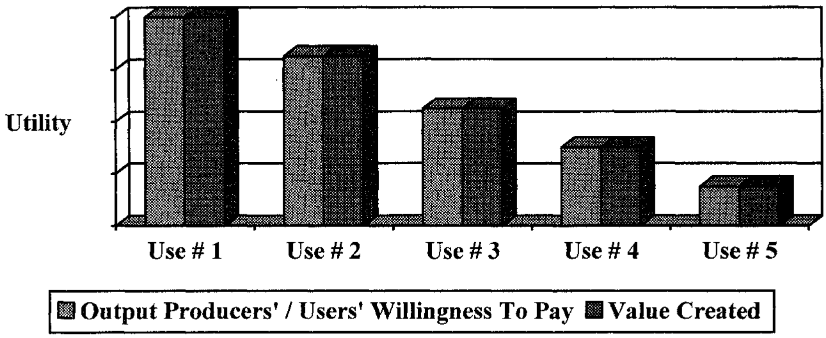
408. *See* Verizon Communications, Inc. v. Law Offices of Curtis V. Trinko LLP, 540 U.S. 398 (2004); SPENCER WEBER WALLER, ANTITRUST AND AMERICAN BUSINESS ABROAD § 16.4 (3d ed. 2004) (detailing the European Union's treatment of essential facilities and comparing that treatment to U.S. antitrust law).

APPENDIX

The seven stylized figures included in this appendix are designed merely to illustrate.

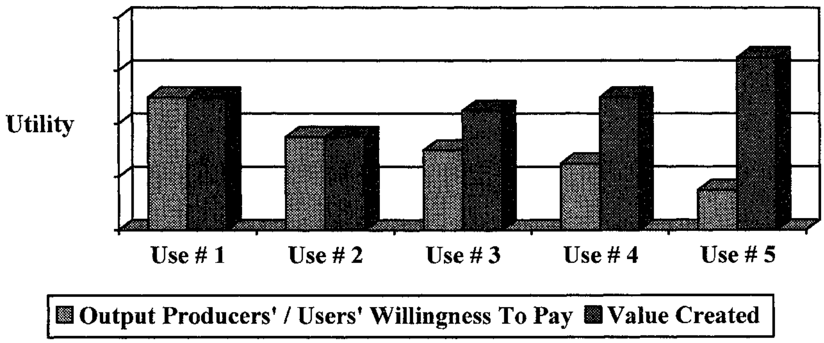
Figure 1: Commercial Infrastructure



<u>Definition</u>: Nonrival or partially (non)rival input into the production of a wide variance of private goods.

<u>Notes</u>: Uses are ranked (1, 2, 3, 4, 5) based on users' willingness to pay. Each use is either purely consumptive or involves using the infrastructure as an input into producing a private good. For each use, then, the amount that users (including direct consumers and output producers) are willing to pay an infrastructure provider for access to the infrastructure matches the utility or value created by obtaining access to the resource.

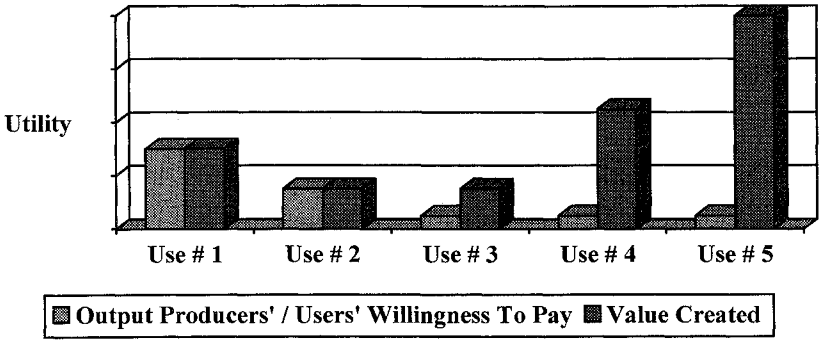
Figure 2: Public Infrastructure



Definition: Nonrival or partially (non)rival input into the production of a wide variance of public goods.

Notes: Uses are ranked (1, 2, 3, 4, 5) based on users' willingness to pay. Uses 1 and 2 are either purely consumptive or involve using the infrastructure as an input into producing a private good. Uses 3, 4, and 5 involve using the infrastructure as an input into producing public goods. For these uses, the amount that users (including output producers) are willing to pay an infrastructure provider for access to the infrastructure matches the utility or value that they may enjoy by obtaining access to the resource which in turn depends on the appropriation of benefits. Output producers do not fully manifest demand for infrastructure access because they do not fully appropriate the benefits of the public goods. *See also infra* appendix figure 5 (illustrating basic research as infrastructure).

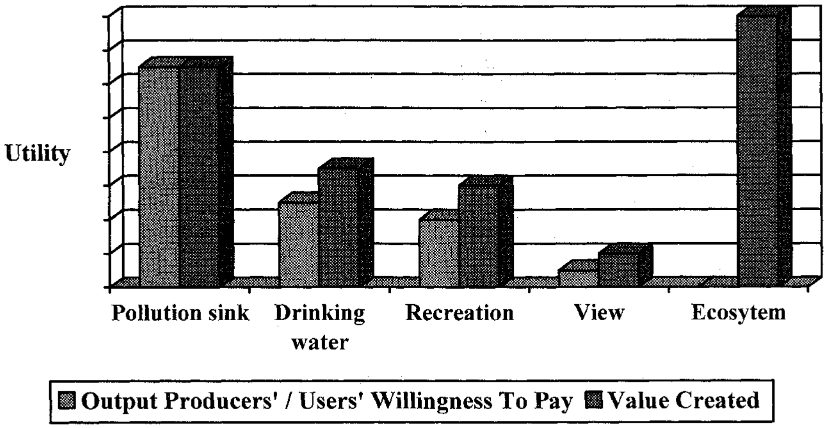
Figure 3: Social Infrastructure



Definition: Nonrival or partially (non)rival input into the production of a wide variance of nonmarket goods.

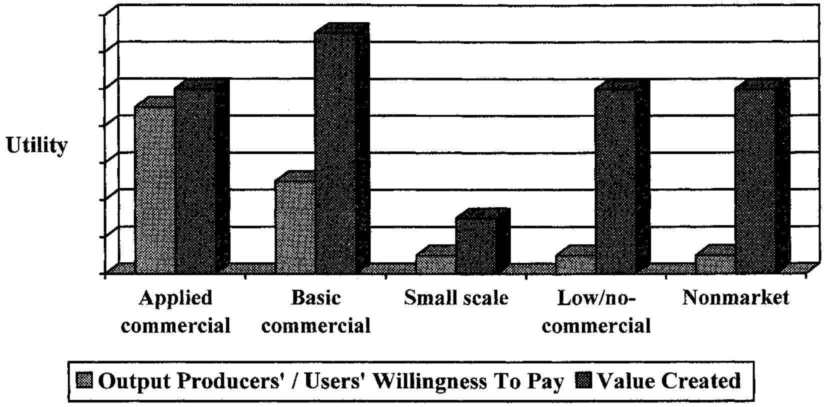
Notes: Uses are ranked (1, 2, 3, 4, 5) based on users' willingness to pay. Uses 1 and 2 are either purely consumptive or involve using the infrastructure as an input into producing a private good. Uses 3, 4, and 5 involve using the infrastructure as an input into producing nonmarket goods. For these uses, the amount that users (output producers) are willing to pay an infrastructure provider for access to the infrastructure matches the utility or value that they may enjoy by obtaining access to the resource which in turn depends on the appropriation of benefits. Output producers do not fully manifest demand for infrastructure access because they do not fully appropriate the benefits of the nonmarket goods. This is a very similar dynamic as seen with public infrastructure; the basic difference is that the benefits of public good outputs often are appropriable to a more significant degree than the benefits of nonmarket good outputs. *See also infra* appendix figure 4 (illustrating a lake as infrastructure).

Figure 4: Lakes as Infrastructure



<u>Notes</u>: Uses are ranked (1, 2, 3, 4, 5) based on users' willingness to pay. Some uses are fully valued by output producers and consumers while others are not. Ecosystem services are not provided by human agents; there is no "output producer" willing to pay for access to the lake. There are some isolated examples of environmental groups buying up land or environmental resources to preserve them.

Figure 5: Basic Research as Infrastructure



Notes: Uses are ranked (1, 2, 3, 4, 5) based on users' willingness to pay. Applied commercial research (Use 1) yields appropriable returns and likely some positive externalities. This type of research tends to be more predictable, less risky, and generally has a short-term focus. Basic commercial research (Use 2) has the potential to yield both appropriable returns and a larger degree of positive externalities. This type of research tends to be less predictable, more risky, and generally has a longer-term focus than applied research. By "small scale" (Use 3), I mean to refer to the small scale production of research results that are not necessarily applied or commercial. Individual researchers, educators, or other members of the public may learn from and extend basic research results in directions not focused on by commercially driven entities. "Low/no-commercial" uses (Use 4) refers more generally to basic and applied research that springs from basic research but is not directed at ends with high commercial value (e.g., vaccine research relevant to developing country populations).* Finally, "nonmarket" uses (Use 5) refers broadly to pure science and other nonmarket production processes. With respect to the latter two categories of uses, there may not be prospective users that are willing to pay for access to basic research results in the absence of government or nonprofit funding. Yet such research has the potential to yield substantial positive externalities and social surplus. Keep in mind that the stylized figure is illustrative; the relative values assigned to uses are arbitrary.

* *See generally* Rai, *Proprietary Rights and Collective Action*, *supra* note 219; Kevin Outterson, *Pharmaceutical Arbitrage: Balancing Access and Innovation in International Prescription Drug Markets*, 5 YALE J. HEALTH POL'Y L. & ETHICS 193 (2004).

Figure 6: Network *Neutrality* Balancing: An Oversimplified View of the Current Debate

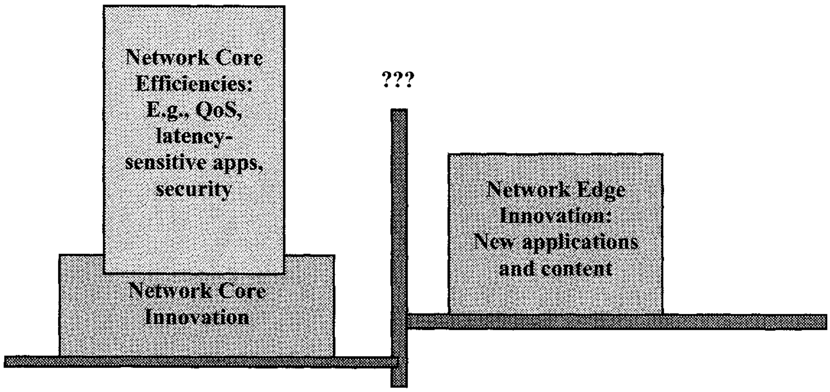


Figure 7: Network *Neutrality* Balancing: Modified by Infrastructure Theory