Note to readers: This is a work in progress with a number of sections "under construction." I welcome comments, questions and suggestions.

AN ECONOMIC THEORY OF INFRASTRUCTURE AND SUSTAINABLE INFRASTRUCTURE COMMONS

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INTRODUCTION

The open access (commons) vs. private control debate is raging. It takes place in a number of fields, including the intellectual property and cyberlaw literatures, as well as broader public debates concerning propertization, privatization, deregulation, and commercialization of such diverse things as communications networks, government services, national forests and scientific research. On the private control side, there is robust economic theory in support of the market mechanism with minimal government regulation. By contrast, on the open access side, there is a frequent call for protecting the "commons," but the theoretical support for this prescriptive call is underdeveloped from an economics perspective. In fact, many that oppose propertization, privatization, deregulation, and commercialization view economics (the discipline) with sincere suspicion and doubt.

In this article, I embrace economics and develop a theory of infrastructure that better explains why, for this particular class of important resources, there are strong economic arguments for managing and sustaining the resources as commons. The approach taken differs from conventional analyses in that it focuses extensively on demand-side considerations and fully explores how infrastructure resources generate value for consumers.

The key insights from this analysis are that infrastructure resources generate value as inputs into a wide range of productive processes and that the

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outputs from these processes are often public goods and nonmarket goods that generate positive externalities that benefit society as a whole. Managing such resources as a commons is socially desirable when doing so facilitates these downstream activities.

Part I provides an overview of this article, situates the analysis within existing scholarship, and explains the connection between infrastructure and commons. Section A explains that traditional infrastructure resources generally are managed as commons because such resources present a "comedy of the commons" rather than a "tragedy of the commons." Section B explains how commons can be understood as a resource management principle that can be implemented through a wide variety of institutions.

Part II explores economic characteristics of infrastructure, first focusing on the traditional economic concepts used in a welfare analysis of infrastructural goods and then delving deeper in an attempt to better understand societal demand for infrastructure resources. Section A explores the key economic characteristics that one must understand to appreciate the demand-side analysis of infrastructure. Section B develops a demand-side model of infrastructure. It begins with a general definition of infrastructure comprised of three demand-side criteria discussed in section A and common to traditional and non-traditional infrastructure resources. Next, it develops an infrastructure typology to distinguish between commercial, public and social infrastructure based on the nature of the productive activities facilitated by an infrastructure resource and the potential for these activities to generate positive externalities. Section C compares infrastructure and network effects with respect to the potential for demand-side externalities. Section D evaluates the economic arguments for managing different types of infrastructure resources as commons.

Putting the economic theory in context, Part III illustrates how certain environmental and information resources behave economically as infrastructure. Specifically, I focus on lakes and basic research and explain how these resources are fundamental inputs into a wide range of productive activities that yield positive externalities that benefit society as a whole. I explain how 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 commons.

Part IV applies the theory 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 will retain its current end-to-end design and continue to be managed as a commons. Ultimately, the outcome of this debate will determine whether the Internet continues to operate as a mixed infrastructure, or whether it evolves into a commercial infrastructure optimized for a particular class of outputs—the delivery of commercial content for consumption. I argue that the current debate is skewed because it focuses myopically on neutrality, competition theory, and innovation. A new lens is needed because there is much more at stake than the current debate reflects. The Internet is a fundamental public and social Infrastructure that is "transforming our society."[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 are being transformed by the Internet. 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, 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.

[1] PRESIDENT'S INFO. TECH. ADVISORY COMM., INFORMATION TECHNOLOGY RESEARCH: INVESTING IN OUR FUTURE 11, 11-20 (Feb. 1999), available at http://www.ccic.gov/ac/report/pitac_report.pdf.

[2] *Id*. at 11.

[3] *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.").

I. FROM INFRASTRUCTURE TO COMMONS

Scholars in a number of fields have been struggling to determine whether particular resources should be managed as "commons," which means that the resource is openly accessible to all within a community regardless of their 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 a significant interest in the concept of managing resources as commons, there is considerably less explanation as to how we should decide whether doing so would be normatively attractive in particular cases with respect to particular resources.

In THE FUTURE OF IDEAS, for example, Professor Lawrence Lessig makes clear his belief that American society must wake up and make difficult decisions between freedom and control. We must decide, Lessig reminds us, between *freedom and control*, between *open access and restricted access*. These choices must be made with respect to resources—the environment, information, culture, the Internet, and so on. Lessig recognizes at the very outset of his book that there is no simple answer to the question of whether a resource should be free or controlled.[7] The choice is actually a difficult one because it is not really an either-or, binary choice.[8] 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 figuring out how to determine whether particular resources

[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*, Sept. 1998, *available at* http://www.law.nyu.edu/benklery (last visited May 31, 2002) (analyzing the commons as "a third, neglected, institutional approach," distinct from "direct government intervention and privatization.").

[6] "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.'" *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 (2004) [hereinafter *Modularity, Vertical Integration, and Open Access Policies*].

[7] LAWRENCE LESSIG, THE FUTURE OF IDEAS: THE FATE OF THE COMMONS IN A CONNECTED WORLD 14 (2001) [hereinafter THE FUTURE OF IDEAS].

[8] LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 14 (The "choice is not between all or none.").

should be managed as a "commons" and if so, to what degree. Throughout his book, Lessig details numerous examples of "free" common resources that benefit society as well as of the ongoing enclosure of many of these resources.[9] He demonstrates how the Internet has altered the landscape and enabled freedom, and he 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 he asks us to make, not only from a process standpoint (as voters or consumers, for example) but also from a normative standpoint. This article is a step in that direction.[10]

Utilizing an economic approach,[11] I define a set of important resources that are particularly attractive candidates for commons management, specifically "infrastructure."[12] My thesis is that if a resource can be classified as infrastructure according to economic criteria set forth in this article, then there is a strong argument that the resource should be managed as a commons (*i.e.*, in an openly accessible manner).[13]

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[9] On the enclosure of public resources, see DAVID BOLLIER, PUBLIC ASSETS, PRIVATE PROFITS: RECLAIMING THE AMERICAN COMMONS IN AN AGE OF MARKET ENCLOSURE.

[10] 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).

[11] In terms of figuring out what is normatively attractive, I adopt an economic approach focused on maximizing social welfare. I recognize that such as 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 (White Paper for the Brennan Center for Justice) (March, 2001) [hereinafter CORE COMMON INFRASTRUCTURE].

[12] Prominent scholars, such as Yochai Benkler and Lawrence Lessig, have relied upon analogies to traditional infrastructure such as highways in support of their prescriptive call for managing other resources as a commons. *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, 100-01 (1998) [hereinafter *Overcoming Agoraphobia*]. Both Benkler and Lessig have focused on resources associated with our "networked information economy." Yochai Benkler, *Lecture: Freedom in the Commons: Towards A Political Economy of Information*, 52 DUKE L.J. 1245, 1251 (2003) [hereinafter *Freedom in the Commons*].

[13] In a series of publications, Yochai Benkler has advanced a powerful set of arguments in favor of developing a "core common infrastructure—a set of resources necessary to the production

A. Infrastructure

The term "infrastructure"[14] generally conjures up the notion of physical resource systems made by humans for public consumption.[15] A list of familiar examples includes: *transportations systems*, such as highway and road systems, railways, airline systems, ports, etc., (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 will refer to these resources as "traditional infrastructure."[16]

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and exchange of information, which will be available as commons." Benkler, *Freedom in the Commons*, *supra* note 12, at 1273; *see* Benkler, *Coase's Penguin, or, Linux and the Nature of the Firm*, 111 YALE L.J. 369 (2002) [hereinafter *Coase's Penguin*]; Benkler, *The Battle Over the Institutional Ecosystem in the Digital Environment*, 44 COMMUNICATIONS OF THE ACM No.2 84 (2001) [hereinafter *Battle Over the Institutional Ecosystem*]; Benkler, CORE COMMON INFRASTRUCTURE, *supra* note 11; Benkler, *From Consumers to Users: Shifting the Deeper Structures of Regulation Towards Sustainable Commons and User Access*, 52 FED. COMM. L.J. 561 (2000) [hereinafter *From Consumers to Users*]. As discussed below, many of the arguments advanced here are complementary to those advanced by Professor Benkler.

[14] *See* BLACK'S LAW DICTIONARY DELUXE SEVENTH EDITION WEST (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 3RD NEW INTERNATIONAL DICTIONARY UNABRIDGED (1986) ("Infrastructure - the underlying foundation or basic framework (as of an organization or a system): substructure esp.: the permanent installations required for military purposes."); RANDOM HOUSE DICTIONARY OF THE ENGLISH LANGUAGE: THE UNABRIDGED EDITION (1973) ("Infrastructure - 1) the basic underlying framework or features of a system, as the military installations, communication and transport facilities of a country. 2) a clandestine system or framework for supporting and implementing unlawful or subversive activities."); THE OXFORD ENGLISH DICTIONARY 2nd Ed. (J.A. Simpson and E.S.C. Weiner 1989) ("Infrastructure - A collective term for the subordinate parts of an undertaking; substructure, foundation; Spec. the permanent installations forming a basis for military operations, as airfields, naval bases. Training establishments etc."); *see also* Morris Dictionary of Word and Phrase Origins 2nd edition William and Mary Morris Harper Collins New York, NY (1967) (providing historical account of how the terms meaning has evolved).

[15] As I will discuss below, conceiving of some natural resources as infrastructure helps to explain intuitive connections between these resources and others (such as information), as well as the normative basis for managing these resources as commons. *See infra* Part III.

[16] I consider the traditional economics of traditional infrastructure below. I then develop an economic model of infrastructure that "fits" both traditional infrastructure and nontraditional infrastructure. This model better explains why traditional infrastructure are managed as a commons and why nontraditional infrastructure should be managed as a commons. *See infra* Part II.

There are two generalizations about traditional infrastructure that are worth noting at the outset.[17] First, the government has played and continues to play a significant and widely accepted role in ensuring the provision of many traditional infrastructure. While private parties and markets play an increasingly important role in the provision of many types of traditional infrastructure (due to a wave of privatization as well as cooperative ventures between industry and government),[18] the government's position as provider, coordinator, or regulator of traditional infrastructure provision remains intact in most communities.[19]

Second, traditional infrastructure generally are managed as a commons. That is, traditional infrastructure are managed in such a way that the resources are openly accessible to members of a community who wish to use the resources.[20] As Mark Cooper notes, "[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 non-discriminatory basis."[21] This does not mean access is free. We pay tolls to access highways, we buy stamps to send letters, we pay telephone companies to have our calls routed across their lines, and so on.[22] Users must pay for access to some (though not all) of these

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[17] Of course, there are exceptions to these generalizations.

[18] *See* SIDNEY M. LEVY, BUILD, OPERATE, TRANSFER: PAVING THE WAY FOR TOMORROW'S INFRASTRUCTURE 1, 16-17 (1996).

[19] The rebuilding of Iraq brings this point into stark relief. The task of reconstructing and rebuilding a country's traditional infrastructure (transportation, communication, governance, basic services) is a tremendous task requiring centralized coordination and substantial investment. Note that building these infrastructure is a necessary precursor to many other productive activities.

[20] *See* Carol Rose, *The Comedy of the Commons: Custom, Commerce, and Inherently Public Property*, 53 U. CHI. L. REV. 711, 752 (1986) [hereinafter *The Comedy of the Commons*]; Benkler, CORE COMMON INFRASTRUCTURE, *supra* note 11, at 22-23, 47-48; LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 19-25. *See generally* Rose, *supra* (discussing the history of public access rights to various infrastructure resources such as roadways, waterways and utilities).

[21] Mark Cooper, *Making the Network Connection: Using Network Theory to Explain the Link Between Open Digital Platforms and Innovation* (2004) working draft at http://cyberlaw.stanford.edu/blogs/cooper/archives/network%20theory.pdf [hereinafter *Making the Network Connection*].

[22] 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 '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 STUDY, THE LONG-TERM BUDGET OUTLOOK, (Dec. 2003) at http://www.cbo.gov/ftpdocs/49xx/doc4916/Report.pdf; CONG. BUDGET OFFICE PAPER, THE ECONOMIC EFFECTS OF FEDERAL SPENDING ON INFRASTRUCTURE AND OTHER INVESTMENTS (June 1998) at http://www.cbo.gov/ftpdocs/6xx/doc601/fedspend.pdf; OECD ECONOMIC STUDIES, THE

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 who you are and how you are using the resource; accessibility generally does not turn on the identity of the end-user or end-use.[23]

As discussed below, managing traditional infrastructure in this fashion makes economic sense.[24] Most economists agree that traditional infrastructure

DRIVING FORCES OF ECONOMIC GROWTH: PANEL DATA EVIDENCE FOR OECD COUNTRIES (June 2001).

[23] In some situations, access to an infrastructure resource is priced at different rates for different classes of users. For example, telecommunications companies historically have treated businesses and individuals differently without much concern. Such (imperfect) price discrimination is justified on the grounds that it better allows producers to recoup production costs under a regulatory regime that mandates universal service, an interesting form of commons policy. Christopher Yoo, *Rethinking the Commitment to Free, Local Television*, 52 EMORY L.J. 1579, 1623 (2003) For other resources (consider for example, a lake), a particular type of use (*e.g.*, pollution) is regulated in order to preserve open access for all other types of use (*e.g.,* swimming, fishing, boating, drinking water source, to name a few). *See infra* part III.A.

[24] *See infra* Part II.A (discussing the economics of traditional infrastructure).

resources generate significant positive externalities[25] that result in "large social gains."[26]

Carol Rose was the first to draw an explicit, causal connection between open access and these positive externalities.[27] In her pathbreaking article, *The Comedy of the Commons: Custom, Commerce, and Inherently Public Property*,[28] Carol 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.[29] With respect to road systems, for example, Rose considered commerce to be an "interactive practice whose exponential returns to increasing

[25] The term "externality" means many things and has been a contested concept in economics for many years. *See* ANDREAS A. PAPANDREOU, EXTERNALITY AND INSTITUTIONS (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* J.E. MEADE, THE THEORY OF ECONOMIC EXTERNALITIES: THE CONTROL OF ENVIRONMENTAL POLLUTION AND SIMILAR SOCIAL COSTS (1973) ("An external economy (diseconomy) is an event which confers an appreciable benefit (inflicts an appreciable damage) 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 Markets versus Non-market Allocation*, *in* PUBLIC EXPENDITURE AND POLICY ANALYSIS, 59 (eds. Haveman & Margolis, 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.

[26] W. Edward Steinmueller, *Technological Infrastructure in Information Technology Industries*, *in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 117, 117 (Teubal et al., eds. 1996).

[27] Harold Demsetz came close. In his article, *Toward a Theory of Property Rights*, Demsetz suggested that "communal property results in great externalities. The full costs of the activities of an owner of a communal property right are not borne by him, nor can they be called to his attention easily by the willingness of others to pay him an appropriate sum." Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. PAPERS & PROC. 347, 348 (1967). 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* Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, Draft Paper at 18-19 (on file with the author) (2004) [hereinafter *Property, Intellectual Property, and Free Riding*].

[28] Rose, *The Comedy of the Commons*, *supra* note 20.

[29] *Id*. at 768-770.

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."[30]

Critically, as Rose recognized, managing road systems as a commons is the key to sustaining and increasing participation in commerce, and commerce is itself a productive activity that generates significant positive externalities. Commerce is one excellent example of a productive use of roads that generates positive externalities and social surplus, but there are many others, such as visiting relatives or state parks.[31]

Understanding *how* traditional infrastructure generate positive externalities and *why* such resources are managed as commons is an important first step to understanding why other resources should be managed in a similar fashion. The same rationale for managing traditional infrastructure as a commons applies to other resources that behave economically in the same fashion as traditional infrastructure, even though they generally are not considered to be infrastructure.[32] I will refer to such resources as "nontraditional infrastructure."

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[30] *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, 143 (1998) ("As 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.").

[31] *C.f.* Lewis M. Branscomb & James H. Keller, *Introduction: Converging Infrastructures*, *in* CONVERGING INFRASTRUCTURES: INTELLIGENT TRANSPORTATION AND THE NATIONAL INFORMATION INFRASTRUCTURE 1 (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.").

[32] 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 as a commons, *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, Lessig, relying on Carol Rose, 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." LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 87. He discusses a town square as a second example, and then suggests in both cases, the resources are managed as commons because it would be unfair to allow a private owner to capture the resource's value because the value increases with the number of users. *Id.* at 87-88. First, private control might be inefficient because the owner might restrict access due to holdouts (strategic behavior), according to Lessig and Rose. *Id.* Second, private control might be inequitable because, assuming no holdouts, the owner would capture the social surplus that ought to be distributed among consumers that contributed to the value-creation. *C.f. id.* Both of these points reflect valid concerns. The first, I think, is more likely to be problematic, although for

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.

I develop an economic model of infrastructure that "fits" both traditional infrastructure and nontraditional infrastructure.[33] This model better explains both why traditional infrastructure resources are managed as a commons and why certain nontraditional infrastructure should be managed as a commons. This model serves both descriptive and normative purposes.

Errors of resource classification often infect analysis of legal and social institutions.[34] Too often, analysts classify an infrastructure resource as a public good, network good, or natural monopoly,[35] 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 government to correct the failure, typically assuming that the degree of intervention should be minimal.[36] But market failure for infrastructure is more complex than these

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various reasons in addition to potential holdouts. *See infra* Part II. Lessig goes even further than Rose, however, in suggesting that the argument for managing a resource as a commons depends upon the degree of (un)certainty as to how the resource will be used. *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) (making the same argument with respect to basic and applied research) [hereinafter *Innovation and Institutions*]. I further develop this argument in this paper with respect to both the type of use and the variance of possible uses. *See infra* Part II.

[33] 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.

[34] *C.f.* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27 (arguing that real property rhetoric, theory, and rationale has infected intellectual property law and placed too much emphasis on free riding).

[35] *See infra* Part II.A (discussing classifications).

[36] 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, (June 8, 2001) at http://www.stlr.org/cite.cgi?volume=2&article=1 (last visited Sept. 18, 2003) [hereinafter *Internet Infrastructure*]; *see also* Shubha Ghosh, *Deprivatizing Copyright*, 54 CASE

classifications suggest. To understand and grapple with the additional demand-side complexity, it is necessary to reconceptualize infrastructure.

In the case of 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.[37] Economists (and regulators) generally focus on three types of supply-side issues: (1) excludability, (2) natural monopoly, and (3) anticompetitive behavior. The first issue 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.[38] The second issue relates to the concept 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).[39] The third issue relates to industry structure and the risk of anticompetitive behavior by dominant firms.[40] These issues (and other related supply-side issues) are important but only half of the story.

This article instead focuses on the demand-side issues. The manner in and degree to which infrastructure resources generate value for society remains an under-explored area that warrants further attention, both by economists and those non-economists who rely on economic reasoning to support normative arguments. The problem with focusing on supply-side issues is that important demand-side characteristics of the resource are not taken into account fully by the market mechanism (or the analysts), and consequently there is incomplete evaluation of

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WES. RES. L. REV. 387 (2003) (exploring 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, 306-311 (1996) (critiquing market theory in copyright law); *see generally* Richard Nelson, *Roles of Government in a Mixed Economy*, 6 J. POLICY ANALYSIS & MANAGEMENT 541 (1987) (explaining limits of market failure analysis).

[37] *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* Nicholas E. Flores, *Conceptual Framework 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.").

[38] *See infra* Part II.A (discussing nonexcludability).

[39] *See infra* note 77 (discussing natural monopolies).

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

true social demand for infrastructure resources.[41] This problem is important because it infects institutional analysis by discounting the social benefits (costs) of opening access (restricting access) to infrastructure resources. As Judge Boudin reflected in *Lotus Development Corp. v. Borland Intern., 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*.[42]

Infrastructure resources, in particular, constitute an important class of resources for which society should place "a very high value on public access." Yet conventional economic analysis of many infrastructure resources fails to fully account for how the resources are used as inputs to create social benefits and thus fails to fully account for the social demand for the resources.[43] Economists (regulators, politicians, and others) recognize 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 is not well understood.[44]

[41] *See* Frischmann, *Internet Infrastructure*, *supra* note 36, at 6, 54, 57-58, 69 (market demand for Internet infrastructure is but a fraction of social demand, even assuming that the market functioned at near perfection); Julie Cohen, *Copyright And The Perfect Curve*, 53 VAND. L. REV. 1799, 1809-1810 (2000) [hereinafter Cohen, *Lochner in Cyberspace*] (making the same point in the copyright context); Julie E. Cohen, *Lochner in Cyberspace: The New Economic Orthodoxy in "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."). As discussed above, most infrastructure resources generate significantly large positive externalities that are not captured fully by infrastructure suppliers and thus constitute social surplus.

[42] *Lotus Development Corp. v. Borland Intern., Inc.*, 49 F.3d 807, 819 (1995) (J. Boudin, concurring) (emphasis added).

[43] The economics discipline certainly has the tools to analyze these demand-side issues, tools which I will use throughout this article. My point is that economists have not aimed in this direction.

[44] *See e.g.*, INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT (D.F. Batten & C. Karlsson, eds. 1996); Steven Shavell & Tanguy Van Ypersele, *Rewards v. Intellectual Property Rights*, 44 J.L. & ECON. 525 (2001) ("The 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."); *c.f.* John F. Duffy, *The Marginal Cost Controversy in Intellectual Property*, 71 U.

Critically, many infrastructure resources act as inputs into a wide variance of socially valuable productive activities including the production of public goods and non-market goods.[45] These activities generate significant social welfare gains generally associated with traditional infrastructure yet under-appreciated with respect to nontraditional infrastructure.[46]

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 observe, 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.'"[47]

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

B. Commons as Resource Management

In this article, I will use "open access" and "commons" interchangeably to mean that the resource is openly accessible to users regardless of their identity or

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CHI. L. REV. (2004) ("It is 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.").

[45] *See infra* Part II.A (defining and discussing public goods and non-market goods).

[46] I recognize that I am making 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 non-market goods in an empirical study. Economists have attempted to measure the social surplus generated by infrastructure resources, such as the National Highway system. However, such studies 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, *Contribution of Highway Capital to Output and Productivity Growth in the US Economy and Industries*, Fed. Highway Administration, U.S. D.O.T. (1998).

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

intended use.[48] This may be troublesome to property scholars because there is an important distinction maintained within property scholarship between open access and commons: Open access typically implies absolutely no ownership rights (no property rights) such that there is no exclusion from the resource; all who want access can get access.[49] Commons typically involve 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" while non-members can be excluded.[50] Recent scholarship has analyzed hybrid regimes, such as semicommons, which has attributes of both private and common property.[51]

Put aside these distinctions between property regimes, for now, and simply focus on the accessibility rule—the resource is open to users regardless of their 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 an end in itself; 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.[52]

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[48] *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 12, 19-20 (adopting a similar definition); ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION (1990); PROTECTING THE COMMONS: A FRAMEWORK FOR RESOURCE MANAGEMENT IN THE AMERICAS (Elinor Ostrom et al. eds, 2001); DAVID BOLLIER, PUBLIC ASSETS, PRIVATE PROFITS: RECLAIMING THE AMERICAN COMMONS IN AN AGE OF MARKET ENCLOSURE (2001); *c.f. Estate of Martin Luther King, Jr., Inc. v. CBS, Inc.*, 194 F.3d 1211, 1214 (11th Cir. 1999) (nearly identical definition of a "general publication" in United States 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.").

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

[50] Yochai Benkler, *The Political Economy of Commons*, Upgrade, Vol. IV., No.3 (June 2003). "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.*

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

[52] Frischmann, *Internet Infrastructure*, *supra* note 36, at 59 ("The 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

I am intentionally abstracting from the *institutional form* (property right, regulation, norm, etc.) in order to focus on a particular *institutional function* (opening or restricting access), the management principle itself. Tying form and function together obscures the fact that the management principle can be implemented through a variety of institutional forms, which are often mixed (property and regulation, private and communal property, etc.), and not necessarily through particular forms of property rights.[53] For example, as we will see in Parts III and IV, environmental, information and Internet commons are sustained through very different sets of institutional arrangements. Ultimately, the optimal degree of openness/restrictiveness depends on 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/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?[54] We will explore these

without restriction; no one lays claim to such resources – not the government or private parties. Everyone is 'equally privileged' to use the resource.") (footnotes omitted)

[53] *See* Heverly, *The Information Semicommons*, *supra* note 51, at 131-33; *c.f.* Farrell & Weiser, *Modularity, Vertical Integration, and Open Access Policies*, *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.").

[54] More generally, this subject brings to mind the intimate relationship between inherent and socially constructed characteristics of resources. *See* Dan L. Burk, *DNA Rules: Legal and Conceptual Implications of Biological "Lock-Out" Systems*, CAL. L. REV. (forthcoming 2004); Dan L. Burk, *Lex genetica: The law and ethics of programming biological code*, 4 ETHICS AND INFORMATION TECHNOLOGY 109 (2002); Mike J. Madison, *Rights and Things*, Working Paper (2004) (on file with the author). 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 by social construction with such things as 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 we regularly do these things does not make discussion of inherent characteristics irrelevant. Rather we end up in the middle of the debate mentioned in Part I and are forced first to try and understand what it is that society demands and second to engage in a comparative analysis

specific issues in more detail in Part IV in the context of the ongoing debate over network neutrality and the future of the end-to-end architecture of the Internet.

Thus, 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.[55] Environmental, information, and Internet resources are not inherently commons, in the same way that apples are not inherently private.

There are many ways in which a resource can come to be managed as a commons. A resource may be open for common use naturally, in the sense that it is not "managed" at all, perhaps because it is not (or cannot) owned or controlled by anyone.[56] If there is no rule, norm, custom, decision or the like in place, the resource may be available to all naturally. For example, for most of the Earth's history, the oceans and the atmosphere were natural commons.[57] Why? There are a variety of reasons, including for example, that exercising dominion over such resources was beyond the ability of human beings or simply was not necessary because there was no indication of scarcity.[58]

A resource also may be open for common use as the result of social construction.[59] That is, laws (or rules) may prohibit 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

of provisional mechanisms and institutions. The focus in this article is on the first objective—developing a better understanding of societal demand for infrastructure commons.

[55] Benkler, *The Political Economy of Commons*, *supra* note 50, at 6.

[56] *See* Carol Rose, *Romans, Roads, And Romantic Creators: Traditions Of Public Property In The Information Age*, 66 LAW & CONTEMP. PROBS. 89, 93 (2003) (discussing traditional Roman categories of non-exclusive property, one of which, Res Communes, was incapable of exclusive appropriation due to its inherent character).

[57] *Id.* at 93 ("The usual Roman law examples of res communes resources were the oceans and the air mantle, since they were impossible for anyone to own.").

[58] *Id.*

[59] David and Foray note that the "activity of diffusing economically relevant knowledge is not itself a natural one. Rather, it is socially constructed through the creation of appropriate institutions and conventions, such as open science and intellectual property." 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 87, 91 (Teubal et al., eds. 1996); *see also id.* at 93-99. The open source and creative commons movements are two prominent examples. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7; *see also* J.H. Reichman & Paul F. Uhlir, *A Contractually Reconstructed Research Commons for Scientific Data in a Highly Protectionist Intellectual Property Environment*, 66 LAW & CONTEMPORARY PROBLEMS 315-440 (2003).

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 value of the commons management principle is 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.[60] As a general matter, managing infrastructure resources as commons eliminates the need to rely on either market actors or the government to "pick winners" downstream.[61] In theory at least, this facilitates innovation in the creation of and experimentation with new uses.[62] More generally, it facilitates the generation of positive externalities through the downstream production of public goods and non-market goods that might be stifled under a more restrictive access regime.[63]

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,"[64] a consumption or capacity problem,[65] which is common to many infrastructure resources. Information resources suffer from the famous "free rider" dilemma, a production problem,[66] which also is common to many infrastructure resources. The Internet suffers from both types of problems.[67]

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[60] *See, e.g.*, LAWRENCE LESSIG, FREE CULTURE: HOW BIG MEDIA USES TECHNOLOGY AND THE LAW TO LOCK DOWN CULTURE AND CONTROL CREATIVITY (2004); LESSIG, THE FUTURE OF IDEAS, *supra* note 7; WILLIAM M. LANDES & RICHARD A. POSNER, THE POLITICAL ECONOMY OF INTELLECTUAL PROPERTY LAW 15-16 (AEI Press 2004) (acknowledging such benefits with respect to the public domain). As we will see in Part IV, however, managing the Internet as a commons presents a more complicated picture because an open access regime may favor data applications as a class over latency-sensitive applications such as IP telephony or video-on-demand. *See, e.g.*, Tim Wu, *Network Neutrality and Broadband Discrimination*, 2 J. TELECOM. & HIGH TECH 141 (2003); Christopher S. Yoo, *Would Mandating Broadband Network Neutrality Help or Hurt Competition? A Comment on the End-to-End Debate*, 3 J. TELECOMM. & HIGH TECH. L. (forthcoming Fall 2004) (manuscript at 15, on file with author at http://law.vanderbilt.edu/faculty/yoo.html).

[61] I discuss this point in more detail below. *See infra* Part II.D.

[62] *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7.

[63] *See infra*.

[64] *See generally* Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

[65] *See infra* note Part II.B and accompanying text (discussing this problem) and Part III.A (discussing environmental resources).

[66] *See infra* Part II.B (discussing this problem) and Part III.B (discussing information resources).

[67] *See infra* Part IV.

These problems are not insurmountable and should not stand in the way of managing infrastructure as commons. Both the tragedy of the commons and the free rider stories point in the direction of controlling access to the resource through property rights.[68] And yet in each of these areas, social institutions reflect a strong commitment to sustaining common access to certain infrastructural resources.[69] Society values common access because these resources are fundamental inputs into productive activities that generate benefits for society as a whole.

II. A DEMAND-SIDE THEORY OF INFRASTRUCTURE

In this part, I explore some economic characteristics of infrastructure, first focusing on the traditional economic concepts used in a welfare analysis of infrastructural goods[70] and then delving deeper in an attempt to better understand societal demand for infrastructure resources. Keep in mind that when discussing demand, I am talking about human desire to realize value (or utility), and when discussing societal demand, I am talking about society's aggregated desires. With respect to infrastructure resources, I would like to 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 proceed to analyze and compare provisional mechanisms (in other words, supply systems such as

[68] It is interesting how two frequently told stories of unconstrained 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 solution. 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. *See, e.g.*, ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 3 (1990) (tragedy of the commons / prisoners' dilemma); Shubha Ghosh, *Rethinking the Patent Bargain Metaphor: Market Integrity, Reciprocity and the Assurance Game*, Working Paper (2004) (on file with author) (free riding / prisoners' dilemma); *c.f.* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27 ("Free riding seems to be the flip side of the tragedy of the commons."); David Driesen & Shubha Ghosh, *The Functions of Transaction Costs: Rethinking Transaction Cost Minimization in a World of Friction,* Working Paper at 24, (2004) (on file with author) (suggesting that the goal of minimizing transaction costs in both private law and public law settings "tends to support private markets and private law, while disfavoring established public law" and challenging the desirability of that goal).

[69] *See infra* Parts III and IV.

[70] A survey the entire field of infrastructure economics is beyond the scope of this article (and probably would be distracting from the central point).

markets, government, community, family, and so on), and institutions aimed at optimizing these mechanisms (for example, law, norms, subsidies, taxes, and so on). This is because a critical aspect of comparative analysis concerns the relative effectiveness of these mechanisms' capacity to generate, communicate, process and respond to demand signals.

The economics of traditional infrastructure are quite complex. This is reflected perhaps in the fact that economists sometimes refer to infrastructure "opaquely" as "social overhead capital."[71] As observed by W. Edward Steinmueller:

> 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 transportation and communications modalities have become so pervasive, that they have come to be taken as a defining characteristic of industrialized nations.[72]

As noted above, traditional infrastructure include a wide variety of resources, including *transportations systems*, such as highway and road systems, railways, airline systems, ports, etc., (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. Not surprisingly, in addition to the study of the economics of regulation and natural monopolies in general, economists have focused their attention more specifically on the economics of infrastructure resources in these particular

[71] Kenneth Button, *Ownership, Investment and Pricing of Transport and Communications Infrastructure*, *in* INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT 145, 148 (D.F. Batten & C. Karlsson, eds. 1996).

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

industries.[73] Further, economists have examined the role that infrastructure investment has on economic development, particularly in the context of developing nations and their economic policies.[74]

As noted above, analysts tend to classify infrastructure resources as public goods,[75] network goods,[76] natural monopolies,[77] or some combination thereof,

[73] *See* VISCUSI, VERNON & HARRINGTON, ECONOMICS OF REGULATION AND ANTITRUST, chapters 11-15 (1992) (discussing economics of various infrastructure resources).

[74] *See, e.g.*, INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT (D.F. Batten & C. Karlsson, eds. 1996); SIDNEY M. LEVY, BUILD, OPERATE, TRANSFER: PAVING THE WAY FOR TOMORROW'S INFRASTRUCTURE (1996).

[75] *See* Kenneth Button, *Ownership, Investment and Pricing of Transport and Communications Infrastructure*, *in* INFRASTRUCTURE AND THE COMPLEXITY OF ECONOMIC DEVELOPMENT 145, 151, 155 (D.F. Batten & C. Karlsson, eds. 1996). The public good label does not really fit all traditional infrastructure resources perfectly: on one hand, telecommunications networks and courthouses, for example, are subject to congestion, meaning that they are not always nonrivalrously consumed, and, on the other hand, the cost of excluding users of these resources is not always high. *See id.* at 151 (same point with respect to transport and communications infrastructure). *See infra* Part II.A (discussing characteristics of public goods).

[76] *See infra* Part II.D (discussing network effects).

[77] Natural monopoly: Many traditional infrastructure resources have been analyzed by economists as so-called natural monopolies. *See* VISCUSI, VERNON & HARRINGTON, ECONOMICS OF REGULATION AND ANTITRUST, chapters 11-15 (1992). Generally speaking, industries where suppliers of a good (or service) face a "decreasing cost pricing problem" are considered "natural monopolies," meaning that it is efficient to have a single producer supply the good. *Id.* at 330; Ariel Katz, *The Potential Demise of Another Natural Monopoly*, working paper at n.43 (2004) (draft available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=547802#PaperDownload); Richard Posner, *Natural Monopoly and its Regulation*, 21 STAN. L. REV. 548 (1969). Notably, that single producer need not be a for-profit actor. It may be the government or a non-profit entity. VISCUSI, VERNON & HARRINGTON, ECONOMICS OF REGULATION AND ANTITRUST, *supra*, ch. 14. There are a host of regulated monopolies in the United States that provide essential infrastructure. *See* Richard Posner, *Natural Monopoly and its Regulation*, 21 STAN. L. REV. 548, 549 (1969).

The natural monopoly problem is in most respects a supply-side issue concerning cost recovery, efficient pricing structures, managing entry, and protecting consumers from monopoly-inflated prices. RICHARD A. POSNER, AN ECONOMIC ANALYSIS OF LAW 363 (6th Ed. 2003). There may be some interesting demand-side issues, however. In particular, natural monopoly classification (or declassification) usually depends upon both supply and demand information. VISCUSI, VERNON & HARRINGTON, ECONOMICS OF REGULATION AND ANTITRUST 444 (1992). 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. VISCUSI, VERNON & HARRINGTON, ECONOMICS OF REGULATION AND ANTITRUST 444 (1992). 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 & Harrington, such a shift could lead to declassification as a natural monopoly and reclassification as a potentially competitive industry. *Id.* at 445-447. For the remainder of this article, I will put aside natural rely on such a classification as a justification for government intervention, and proceed to analyze regulatory options. In other words, it is generally well-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. In some cases, the government may supplant the market and supply the resource directly or contract directly with providers on behalf of its citizens,[78] and 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 and supply the resource to the public.[79] With respect to the latter set of cases, the question becomes one of comparative institutional analysis—how should the market be modified or regulated. Many of the debates in this area focus on the degree and form of government intervention into the market. Operating on the premise that markets are best at generating and processing demand information (*e.g.,* concerning the quantity and quality of infrastructure access desired by society),[80] the analysis of corrective institutions tends to focus on the supply-side problems noted earlier.[81] Yet the underlying premise is flawed, at least in the respect that it does not hold up for all resources. Specifically, markets are not necessarily better than the government or other alternative, non-market mechanisms[82] at processing information about or meeting the demands of our complex society for public and social infrastructure.[83]

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monopoly theory as it is not especially relevant to the demand side analysis of infrastructure undertaken in this article.

[78] *See Id*., ch. 14 (discussing public enterprise); SIDNEY M. LEVY, BUILD, OPERATE, TRANSFER: PAVING THE WAY FOR TOMORROW'S INFRASTRUCTURE (1996) (discussing procurement and government contracting for infrastructure); Frischmann, *Innovation and Institutions*, *supra* note 32, at 386-87 (same).

[79] *See id.* at 382.

[80] This may be an overstatement. In regulated markets, particularly those involving so-called natural monopolies, regulated entities must make decisions about how to invest in building the infrastructure resources necessary to service consumers, and then, regulators are often involved in verifying that expenditures are justified by demand. In other industries, governments contract with private entities to build infrastructure to meet community demands. For the most part, demand assessments for potentially (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.

[81] *See supra* text accompanying notes 37-40 (listing the three major types of supply-side problems).

[82] *See, e.g.*, Benkler, *Coase's Penguin*, *supra* note 13; Benkler, *Freedom in the Commons*, *supra* note 12; David R. Johnson et al, *The Accountable Net: Peer Production of Internet Governance*, Harvard Public Law Working Paper No. 97 (April 2004) (on file with author).

[83] *See* Frischmann, *Innovation and Institutions*, *supra* note 32, at 387; Benkler, *Coase's Penguin*, *supra* note 13; Cohen, *Perfect Curve*, *supra* note 41, at 1809-1810 ("[L]icensing

This part is structured as follows: Section A explores the key economic characteristics that one must understand to appreciate the demand-side analysis of infrastructure. Section B develops a demand-side model of infrastructure. It begins with a general definition of infrastructure comprised of three demand-side criteria common to traditional and non-traditional infrastructure resources. Next, it develops an infrastructure typology to distinguish between commercial, public and social infrastructure based on the nature of the productive activities facilitated by an infrastructure resource and the potential for these activities to generate positive externalities. Section C compares infrastructure and network effects with respect to the potential for demand-side externalities. Section D evaluates the economic arguments for managing different types of infrastructure resources as commons.

A. Nonrival and potentially (non)rival goods

In this section, I explain why nonrivalry (or potential nonrivalry) is a critical characteristic of infrastructure. 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."[84] For economists, "consumption" simply refers to the realization of benefits by virtue of one's access to the good.

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decisions designed to maximize individual or private welfare may not maximize society's. And because judging the "value" of most cultural works is an inherently subjective exercise, it is not clear that we want any one individual or entity to control decisions about which uses of a work are valuable."). Consider also this excerpt from CORNES & SANDLER:

> Economists have been criticized, with some justification, for a tendency to forget that institutions other than markets exist and may play important roles in allocating resources. [In the context of externalities,] perhaps 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' action at a busy intersection. 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 26, at 66.

[84] CORNES & SANDLER, *supra* note 26, at 8.

Analysts frequently focus on fitting resources into a classification scheme based on varying degrees of (non)rivalry and (non)excludability:[85]

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

As economists recognize, this classification scheme oversimplifies things because, on one hand, both characteristics (rivalrousness of consumption and excludability) involve a matter of degree, and, on the other hand, these two characteristics often comprise only a piece of the economic puzzle, a point brought into relief in this article.[86]

It is easy to see how excludability varies by degree. When economists talk about excludability what they are referring to is the costs of exclusion; that is, how costly will it be for one person to prevent another from consuming the resource. Consider, for example, ideas and apples. It may be very difficult for me to prevent someone else from consuming an idea. How costly it will be depends upon the context and technology.[87] If I originate an idea, I can prevent others from deriving benefits from the idea if I can keep the idea secret. This may

[85] *See id*., at 9.

[86] Ultimately, the classification scheme is stretched in different directions when we focus on specific goods. "What matters, however, is the structure of incentives and the efficiency and distributional implications of the various feasible structures." CORNES & SANDLER, *supra* note 26, at 10. Shubha Ghosh critiques the classification scheme because it is insufficient in identifying government functions and may be misleading in its prescriptions. *See* Shubha Ghosh, *Deprivatizing Copyright*, 54 CASE WES. RES. L. REV. 387 (2003); *see also* OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 8-15 (1990) (critiquing the taxonomical approach for similar reasons); Hess & Ostrom, *Ideas, Artifacts, and Facilities*, supra note 49, at 118-121 (suggesting that scholars sometimes conflate resource classification with property right issues).

[87] For example, the invention of barbed wire and digital rights management technology greatly reduced the costs of exclusion for land and digital content. *See* DAVID BOLLIER, PUBLIC ASSETS, PRIVATE PROFITS: RECLAIMING THE AMERICAN COMMONS IN AN AGE OF MARKET ENCLOSURE (2001); DAVID BOLLIER, PUBLIC ASSETS, PRIVATE PROFITS: RECLAIMING THE AMERICAN COMMONS IN AN AGE OF MARKET ENCLOSURE, New America Foundation, at http://www.newamerica.net/Download_Docs/pdfs/Pub_File_650_1.pdf.

involve some cost to me, 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, in the sense that it is difficult to maintain exclusive possession. By contrast, it is relatively cheap to maintain exclusive possession of an apple and thereby prevent another person from consuming it.

Excludability is relevant to 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 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 (undersupply) because suppliers will not be able to recoup their costs from consumers. Simply put, a producer of a good needs to be able to exclude you from consuming the good it has produced if it wishes to charge you for access and consumption, and 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 sink 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[88] 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.[89]

[88] It is a mistake to presume, as many do, that the market mechanism is the superior mechanism for satisfying social demand for a resource. *See* Richard Nelson, *Roles of Government in a Mixed Economy*, 6 J. POLICY ANALYSIS & MANAGEMENT 541 (1987); Moshe Justman & Morris Teubal, *Technological Infrastructure Policy (TIP): Creating Capabilities and Building Markets*, *in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 21, 51-52 (Teubal et al., eds. 1996); Benkler, *Coase's Penguin*, *supra* note 13; Cohen, *Perfect Curve*, *supra* note 41, at 1809-1810.; CORNES & SANDLER, *supra* note 26, at 66; *see also supra* note 83 (quoting from CORNES & SANDLER on this point). Such a presumption only makes sense analytically for certain types of resources, such as private goods, for example, because such a presumption may bias comparative institutional analysis. *See* Frischmann, *Internet Infrastructure*, *supra* note 36, at 44 n.138; *c.f.* CORNES & SANDLER, *supra* note 26, 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, but we should not adopt a presumption in favor of the market. The case for must be made for specific resources, even if categorically as I am doing in this article. *See* Justman & Teubal, *supra*, at 51-52. To be clear, for certain public goods and impure public goods, I do believe the market mechanism generally will be preferable, as in the case of commercial infrastructure. *See infra* Part II.B & D.

[89] 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 32, at 359-60, 363-64, 374, 376-82; *see also* Jamie Boyle, *The Second Enclosure*

Rivalrousness of consumption ("rivalry") is a function of capacity[90] and the degree to which one person's consumption of a resource affects the availability of the resource for others.[91] 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 transactions costs and distributional issues, which are important but not relevant to the point being made here, it is widely accepted that social welfare is maximized when a rivalrously consumed good is consumed by the person that values it the most[92]

Movement and the Construction of the Public Domain, LAW & CONTEM. PROBS. 41-42 (2003) at http://www.law.duke.edu/pd/papers/boyle.pdf. [hereinafter *Second Enclosure Movement*] (describing the standard argument); Hess & Ostrom, *Ideas, Artifacts, and Facilities*, supra note 49, at 119 ("[I]t is very costly to exclude individuals from using the flow of benefits either through physical barriers or legal instruments."); Cohen, *Lochner in Cyberspace*, *supra* note 41, 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."); Benkler, CORE COMMON INFRASTRUCTURE, *supra* note 11, at 3 (noting 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 the exclusionary market failure, there is a significant debate as to how intellectual property systems might be optimized. *See, e.g.*, Christopher S. Yoo, *Copyright and Product Differentiation*, 79 N.Y.U. L. REV. 212 (2004); Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J. OF ECON. PERSP. 29 (1991) [hereinafter *Standing on the Shoulders of Giants*]; Mark A. Lemley & Dan L. Burk, *Policy Levers in Patent Law*, 89 VIRGINIA LAW REVIEW 1575 (2003).

[90] 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., 2002) (defining capacity as "the maximum rate at which a computer system can process work"; "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 different facilities, such as data lines, switches, and coaxial cables); *see generally* MERRIAM WEBSTER'S COLLEGIATE DICTIONARY 168 (10th ed. 2000) (defining capacity as "the potential or suitability for holding, storing, or accommodating" and also as "the facility or power to produce, perform, or deploy").

[91] Critically, (non)rivalrousness of consumption measures the degree to which one user's consumption of a resource directly affects another user's consumption possibilities and *not* on how production costs are distributed among users. Nonetheless, it is important to keep in mind that congestion (or crowding) costs and production costs may trade-off against each other in a cost-benefit analysis, for example when one analyzes whether to invest in producing congestion-reducing technology (or simply, additional capacity). *See infra*.

[92] *See* Karl Manheim & Lawrence B. Solum, *An Economic Analysis of Domain Name Policy*, Research Paper No. 2004-7, at 360 (Mar. 2004) (on file with author) (discussing Pareto-efficient

and that the market mechanism is the most efficient means for rationing such goods and for rationing resources into the production of such goods.[93] (Thus, producers of apples are given exclusive control over access to 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 the resource are zero.[94] It is widely accepted by economists 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 at no additional cost. Ideas, like other nonrival goods, have infinite capacity.

It is also widely accepted by economists that a static, ex post perspective on existing resources is only a partial perspective. It is important to incorporate 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)[95] coupled with high fixed costs of production and low marginal costs presents a risk to investors,

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transactions for private goods); Harold Demsetz, *The Private Production of Public Goods*, 13 J.L. & ECON. 293, 295 (1970) (explaining how "rationing of [an existing] inventory [of private goods] by market price minimized the loss in value due to others being excluded from consumption . . . by allocating the inventory to those who find it most valuable.").

[93] *See id.* at 295-96. As Demsetz puts it, "The market price of private goods serves efficiently both the function of rationing the existing inventory and rationing resources into replenishment of the inventory." *Id.* For a nice explanation, see Spulber & Yoo, *Access to Networks*, *supra* note 37, at 895-97.

[94] Note that I have been careful to focus solely on the accessibility rule. I intentionally have not taken into account distribution/transmission costs, which may vary considerably by resource type. *See, e.g.*, Yoo, *Copyright And Product Differentiation*, *supra* note 89, at 231-32 (marginal costs of making and transmitting copies of a copyrighted work varies on a spectrum depending upon, 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").

[95] On the free rider label, see Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27, at 22.

which *may* lead to undersupply by markets.[96] As described succinctly by Christopher Yoo in the context of copyrighted works:

> If authors are to break even, the prices they charge 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 costs needed to make the particular copy sold (which economists call "marginal cost"). If third parties were allowed to copy freely, however, they could price their copies at marginal cost without including any surplus to defray first-copy costs. This would deprive authors of any reasonable prospect of recovering their investments in first-copy costs and would leave rational authors with no economic incentive to invest in the production of creative works.[97]

Taken together, these two perspectives—of static and dynamic efficiency—yield a complicated economic puzzle in terms of figuring out how to maximize social welfare. It *may* be necessary to strike a balance (as a matter of policy) between opening access to reap static efficiency gains and restricting access to reap dynamic efficiency gains. Whether it is necessary to "strike a balance" depends upon the resource, the costs and benefits of doing so, and the alternatives.

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[96] Basically, high fixed costs of production and low (constant 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 77. High costs of exclusion may lead to market failure (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.B.iii (discussing private flower bed example); Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27.

[97] *See* LANDES & POSNER, THE POLITICAL ECONOMY OF INTELLECTUAL PROPERTY LAW, *supra* note 60, at 22-23; Yoo, *Copyright And Product Differentiation*, *supra* note 89, 214-15; Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27, at 22; Mark Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989 (1998); 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 (NBER 1962).

At times, nonrivalry seems inextricably linked to nonexcludability[98] and the associated risk of free-riding.[99] In a 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.[100] Producers of nonrival goods seeking to maximize their returns may face a 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.[101] 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), and not all nonrival goods are even produced (consider, for example, sunshine).

Yet possible free-riding drives analysts to focus on supply-side considerations, and more specifically, to correcting market-driven supply by designing property-based institutions to lessen the costs of exclusion and minimize free-riding.[102] As I have argued elsewhere, non-excludability is not a necessary condition for market failure (*i.e.*, markets may fail for many other reasons), and conversely, exclusion does not fix all failures.[103] In fact, exclusion may aggravate other failures of the market. Even if an owner can exclude users from a nonrival resource and therefore can meter use by charging a fee, dynamic

[98] Harold Demsetz made a similar observation in his seminal article, *The Private Production of Public Goods*, and argued that "[t]here is nothing in the public good concept that disallows the ability to exclude." Harold Demsetz, *The Private Production of Public Goods*, 13 J. LAW & ECON. 293, 295 (1970). Demsetz applied the label "public goods" to nonrivalrously consumed goods, and viewed nonrivalrously consumed, nonexcludable goods as a subset of "public goods" that he referred to as "collective goods." *Id.*

[99] This relates to the point made earlier that analysts (economists and others) tend to focus on the public good classification initially and then swiftly shift to the supply-side analysis of institutions designed to fix the exclusionary market failure without more carefully considering the (potential) benefits of nonrivalrous consumption.

[100] As Mark Lemley notes with respect to intellectual property, "we 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 27, at 22.

[101] Consider excludable goods that exhibit similar cost structures (high fixed costs coupled with low marginal costs, and thus decreasing average costs); for example, a telecommunication network. Such goods do not run into the free-riding problem.

[102] *See* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27.

[103] *See* Frischmann, *Innovation and Institutions*, *supra* note 32; Frischmann, *Internet Infrastructure*, *supra* note 36.

inefficiencies still may abound.[104] Simply put, institutions that lessen the costs of exclusion and facilitate market-driven provision of nonrival goods—essentially, property rights—are not a panacea. As two well-respected economists, Richard Cornes and Todd Sandler, observe:

> 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.[105]

Critically, focusing on free-riding and market-driven supply obscures the economic meaning and importance of nonrivalry.[106] Developing a more sophisticated understanding of what nonrivalry facilitates, *i.e.*, the doors opened for society, is critical to providing a more robust economic argument for commons.[107]

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[104] *See, e.g.*, Cohen, *Perfect* Curve, *supra* note 41, at 1807-1809; Lemley, *The Economics of Improvement in Intellectual Property Law*, *supra* note 97, at 1056-58.

[105] CORNES & SANDLER, *supra* note 26, at 56-57 (citation omitted).

[106] 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 27. 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. LANDES & POSNER, THE POLITICAL ECONOMY OF INTELLECTUAL PROPERTY LAW, *supra* note 60, 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.

[107] *See* Paul A. David & Dominique Foray, *Information Distribution and the Growth of Economically Valuable Knowledge: A Rationale for Technological Infrastructure Policies, in*

In a sense, nonrivalry opens the door to much more than free-riding. When analyzing nonrival (and potentially nonrival resources), it is important to distinguish between consumption goods and intermediate goods (inputs).[108]

Consumption goods are, as the name suggests, 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 is social welfare maximizing, but from a dynamic efficiency perspective, such a policy may lead to market failure (if the good is supplied by the market) because of free-riding concerns.[109]

Intermediate goods are, as the name suggests, 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").[110] This is a door opened by nonrivalry worth exploring more carefully.[111]

TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 87 (Teubal et al., eds. 1996) (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); Benkler, *Coase's Penguin*, *supra* note 13; Boyle, *Second Enclosure Movement*, *supra* note 89, at 44-46 (discussing distributed creativity).

[108] *See* Cohen, *The Perfect Curve*, *supra* note 41, at 1803-04 (explaining that the traditional economic analysis of the supply and demand curves for copyrighted information views the consumer surplus as benefits derived from consumption and not productive use); Lemley, *The Economics of Improvement in Intellectual Property Law*, *supra* note 97, at 1056-58.

[109] 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, *Access to Networks*, *supra* note 37, at 896.

[110] Throughout this paper, I have used input-output terminology to describe resource use in production processes. There are various ways to describe these relationships. One alternative refers to generic or basic inputs as platforms, and, as we will see in Part IV, another refers to the relationships in terms of layers. 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.

[111] The cumulative nature of information production is well recognized in the literature and is the subject of extensive academic study. *See, e.g.*, Scotchmer, *Standing on the Shoulders of Giants*, *supra* note 89; Robert Merges and Richard Nelson, *On Limiting or Encouraging Rivalry in Technical Progress: The Effect of Patent Scope Decisions*, 25 J. ECON. BEHAVIOR & ORG. (1994); Robert Merges & Robert Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 890 (1990); Frischmann, *Innovation and Institutions*, *supra* note 32; Benkler, *The Commons As A Neglected Factor of Information Policy*, *supra* note 5; TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 8 n.2 (Teubal et al., eds. 1996)

Demand for nonrival inputs depends upon the nature of the outputs, and, as discussed in more detail in the next section, evaluating demand may be especially difficult where the outputs are public goods and non-market goods. Yet the social benefits derived from widespread access to a nonrival input used to produce such goods may be quite large.[112] Thus, a demand-side emphasis is critical to valuation of nonrival inputs, both in terms of measurement (*i.e.,* what is 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 into account these issues.

So far, I have discussed extremes, nonrival goods such as ideas and rival goods such as apples. It is important, however, to understand that there are a host of resources in between the extremes, which economists refer to generally as impure public goods.[113] An important subset of these in-between resources includes *potentially (non)rival resources*.

Potentially (non)rival goods are durable goods that have finite, renewable, sharable capacity. These resources *may* be consumed nonrivalrously or rivalrously depending upon the conditions, such as how the resource is managed, the number of users, and the available capacity. I refer to these resources as potentially (non)rival resources because they can be managed in a way that avoids rivalrous consumption. To be clear, we are focusing on how one user's consumption directly affects another user's and not on how production costs are distributed among users. Consider a resource with finite, sharable capacity, a lake or computer network, for example. Up to a point, the marginal costs of allowing

("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.").

[112] *See* Benkler, *Coase's Penguin*, *supra* note 13, at 404 (discussing benefits of peer-production of information); LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 87 (a resource should be managed as commons when the resource is "'most valuable when used by indefinite and unlimited numbers of persons'") (quoting Rose, *The Comedy of the Commons*, *supra* note 20, at 744).

[113] CORNES & SANDLER, *supra* note 26, at 8; *c.f.* 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).

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.[114] This assumed structure does not perfectly fit all resources; deviations will vary across resources. An important 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.[115] Depending upon the number and types of potential uses, the degree to which they compete with each other, and critically, the value each has the potential to generate, we might wish to avoid reaching the congestion point.

From the demand-side, the possibility of avoiding congestion while still allowing multiple users (uses) is what makes the resource potentially nonrivalrous. I recognize that this terminology is bit unusual in the sense that most economists would not characterize pre-congestion 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 really rivalrous.[116]

There is a close connection between potentially (non)rival resources and "club goods."[117] Cornes and Sandler define club goods as a subclass of impure public goods that are partially rival, excludable goods.[118] Cornes and Sandler assume that exclusion is practiced for club goods and analyze decisions as to club membership, provision quantity of the shared resource, and congestion management.[119] Most, if not all, club goods are in fact potentially (non)rival in the sense that they can be managed in a fashion that eliminates congestion (rivalrousness in consumption), for example, by keeping membership size small.[120] As Cornes and Sandler remark in a later chapter of their book, "Congestion is not something that must be completely eliminated; rather an

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[114] *See, e.g.*, CORNES & SANDLER, *supra* note 26 (describing congestible resources); Abraham Bell & Gideon Parchomovsky, *Of Property and Antiproperty*, 102 MICH. L. REV. 1 (2003) (observing that parks are impure public goods that "admit of nonrivalrous uses only to a certain point").

[115] Both lakes and the Internet exhibit variance in these dimensions. *See infra* Parts III.A and IV.

[116] *C.f.* Benkler, *Overcoming Agoraphobia*, *supra* note 12; Benkler, *The Commons As A Neglected Factor of Information Policy*, *supra* note 5 (making this point).

[117] *See* CORNES & SANDLER, *supra* note 26; J.M. Buchanan, *An Economic Theory of Clubs*, 32 ECONOMICA 1 (1965).

[118] CORNES & SANDLER, *supra* note 26, at 9, 349-350.

[119] *See id.* ch. 11.

[120] *See id.* at 348-49.

optimal level of congestion must be found."[121] As discussed below, figuring out the optimal level of congestion is a critical question for infrastructure. For purposes of this article, I have decided to refer to potentially (non)rival resources (rather than impure public goods or club goods) for two reasons: first, to emphasize that the degree of (non)rivalrousness of consumption is variable and often manageable, and second, to emphasize that the means for managing congestion is also variable, as I discuss below.[122]

Table Two		
RIVALROUSNESS OF CONSUMPTION	**Nonrival**	Pure public good (idea)
	Potentially (non)rival	Impure public good (lake, road, Internet)
	Rival	Private good (apple)

Many potentially (non)rival resources are *sometimes* nonrivalrously consumed and *sometimes* rivalrously consumed, depending upon the number of users and available capacity at a particular time.[123] Consider highways (in real-space and Cyberspace),[124] for example. Consumption of these resources is often nonrivalrous, for example, during off-peak hours. 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 threshold, however, determined in terms of aggregate capacity being used, nonrivalrous consumption turns rivalrous and congestion problems arise. Congestion on the highway or on the Internet is a function of finite capacity and variable demand. As a general matter, congestion

[121] *Id.* at 524-25.

[122] 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).

[123] *See* Frischmann, *Internet Infrastructure*, *supra* note 36, at 25-34 (modeling the Internet interconnection infrastructure as a sometimes rivalrous good).

[124] The "information superhighway" metaphor has been critiqued by many, and rightly so, in my opinion, to the extent the metaphor is used as a means of elucidating the relevant "facts of the Internet" in a legal dispute. *See* Brett Frischmann, *The Prospect of Reconciling Internet and Cyberspace*, 35 LOYOLA U. CHI. L. REV. 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.

dissipates over time and the capacity of the resource is renewed. Thus, it is not permanently depleted, unless the system is overwhelmed and crashes.[125]

Like a door that may be closed, opened, or left partially open, potentially (non)rival resources present choices.[126] 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 certain potentially (non)rival goods are subject to capacity expansion, for example, highways or telecommunications systems. Others are not, for example, an environmental resource that acts as a sink for pollutants.

For expandable infrastructure resources, the costs of expansion (*e.g.*, adding more lanes to the highway or more fiber optic cables to the Internet network) must be weighed against the costs of congestion (*e.g.*, traffic slow down) and/or the costs of regulating use in a manner that prevents congestion (*e.g.*, prohibiting certain traffic during peak load times).[127] Instead of building a "whole lot of capacity" (some of which might be excess during certain periods of time, for example), we might prefer to regulate certain types of uses. For example, imagine that if we keep a certain class of vehicle (big trucks) off the highway during rush hour, then we can keep the highway completely open for all other types of vehicles without suffering any congestion, meaning the marginal costs of each additional allowable vehicle (non-big-truck) is zero. I recognize that this type of management scheme itself imposes costs on the regulated vehicles to avoid congestion costs on the unregulated vehicles. Rather than spreading the costs of "a whole lot of capacity" on all users (or perhaps on the entire tax base), displacement costs are placed on a particular class of users. Choosing between "a whole lot of capacity," some capacity with regulation of certain uses, and some capacity with some congestion is difficult and will vary for different resources.

Further, if expansion is desirable, it is necessary to figure out where the investment will come from.[128] If, on one hand, capacity expansion is to be

[125] Some infrastructure resources are more vulnerable to crashing than others. *See* Robert Wilson, *Architecture of Power Markets*, at 4, Research Paper No. 1708, Stanford University School of Business (Sept. 2001) (discussing technological transmission constraints and vulnerability to "instability, cascading failures, or collapse at great cost").

[126] "Closing the door" entails "enclosure" of the resource. *C.f.* Boyle, *Second Enclosure Movement*, *supra* note 89.

[127] *See infra* Parts III.A and IV (using examples to illustrate tradeoffs).

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

financed privately, then private actors may push for private ownership and control over 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 (price),[129] the government (command and control),[130] norms, or even technology to avoid congestion.[131] Such institutional structures must be evaluated carefully and contextually.

* * *

To be clear, not all nonrival or potentially (non)rival goods are infrastructure, and not all nonrival or potentially (non)rival goods should be managed in a manner that takes advantage of nonrivalry. First, to qualify as

> 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, *Access to Networks*, *supra* note 37, at 885. In sonme cases, it may be desirable, from a social welfare perspective, to have excess capacity and "hasten[] the need for additional capacity" for public and social infrastructure.

[129] *See* Benkler, *Overcoming Agoraphobia*, *supra* note 12, at 63 ("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.").

[130] *See infra* Part III.A (discussing regulation of consumptive uses).

[131] "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.

"infrastructure,"[132] the resource must act as an input into the production of a wide variety of outputs. Second, even if a resource can be characterized as infrastructure, whether or not it should be managed in a manner that takes advantage of nonrivalry (*i.e.*, as a commons) will depend upon the context and the mix of outputs. The next section addresses these questions.

B. A demand-side model of infrastructure

In this section, I develop 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 human beings that obtain access to infrastructure resources.

1. A general definition

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

(1) The resource is (or 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 is used as an input into a wide range of goods and services, including private goods, public goods and/or non-market 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 potentially (non)rival goods, the importance of which I discussed in detail in the previous section. Simply put, (potential) nonrivalry opens the door to widespread access and productive use of the resource. For nonrival resources of infinite capacity, the marginal costs of allowing an additional person to access the resource are zero.[133] For potentially (non)rival resources of finite capacity, the

[132] For purposes of this article, at least.

[133] Again, to be clear, allowing access and providing access are two different things. Allowing access simply means not restricting access or erecting barriers to access. If marginal distribution

cost-benefit analysis is more complicated, as suggested in the previous section, but the potential for an open door or partially opened door must be taken into account when evaluating provisional mechanisms (*i.e.*, supply systems such as markets, government, community, family, individual), and institutions aimed at optimizing these mechanisms (*e.g.*, law, norms, subsidies, taxes, and so on).

The second and third criteria are focused 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.[134] Essentially, infrastructure resources are enabling "platforms" upon which others build.[135]

The third criterion emphasizes both the variance of downstream outputs (in other words, the *genericness* of the input) and the nature of those outputs (particularly, the production of public goods and non-market goods).[136] The

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costs are greater than zero, which will often be the case, then I would presume, as a general matter, that the person seeking access is required to bear those 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 that I am focusing on the demand-side; so the point is that allowing consumers to access the resource has no impact on the availability of the resource for other consumers.

[134] For some infrastructure resources, all of the value is derivative, while for other infrastructure resources, there is a balance between productive use and consumption. For purposes of this article, I am not concerned with drawing a bright line on this point.

[135] "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." Shane Greenstein, *The Evolving Structure of the Internet Market*, *in* UNDERSTANDING THE DIGITAL ECONOMY 155 (Erik Brynjolfsson and Brian Kahin, eds., 2000). *See* ANNABELLE GAWER & MICHAEL A. CUSUMANO, PLATFORM LEADERSHIP: HOW INTEL, MICROSOFT AND CISCO DRIVE INNOVATION (2002), at 55-56 (quoted in Cooper, *Making the Network Connection*, *supra* note 21) (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.").

[136] *See* Moshe Justman & Morris Teubal, *Technological Infrastructure Policy (TIP): Creating Capabilities and Building Markets*, *in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 21, 23 (Teubal et al., eds. 1996) (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 59, 60 (Teubal et al., eds. 1996) (similarly defining technological

reason for emphasizing variance and the production of public goods and non-market 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.[137] The information problems associated with assessing demand for the resource and valuing its social benefits plague both infrastructure suppliers and consumers where consumers are using the infrastructure as an input into the production of public goods or non-market goods. This is an information problem that is pervasive and not easily solved.[138]

Whether we are talking about transportation systems, the electricity grid, basic research (ideas), environmental ecosystems, or Internet infrastructure, the downstream benefits created by end-users that rely on the infrastructure, and thus the social demand for the infrastructure itself, are extremely difficult to measure. And yet the bulk of the social benefits generated by the resource derive from the downstream uses.

For example, a road system 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,[139] but the bulk of social benefits attributable to a road system come from the activities it facilitates at the ends, including, for example, commerce, labor, communications, recreation, etc.[140] As recognized by the National Research Council, "Infrastructure 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 infrastructure

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infrastructure as generic and jointly used inputs); *see also* Justman & Morris Teubal, *supra*, at 24 n.5 (describing genericness as having broad relevance from a demand perspective for multiple users/uses).

[137] This may give rise to market failure that is related to but still different and more complicated than traditionally given for 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 need to carefully consider the institutional response—whether substitution of an alternative provider or institutional intervention into the market to improve its performance. This institutional analysis needs to take into account the ways in which infrastructure resources differ from ordinary public goods. *See* Gregory Tassey, *Infratechnologies and Economic Growth*, *in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 59, 67-72 (Teubal et al., eds. 1996) (describing a variety of technology-based market failures).

[138] *C.f.* Benkler, *Overcoming Agoraphobia*, *supra* note 12, at 80-82, 102 (discussing information and transaction cost problems "associated with articulating and communicating preferences about the use of communications infrastructure in an imperfect market").

[139] *See* Benkler, CORE COMMON INFRASTRUCTURE, *supra* note 11, at 22 (discussing benefits of driving on the open road).

[140] Rose, *The Comedy of the Commons*, *supra* note 20, at 768-770; *see also* Benkler, CORE COMMON INFRASTRUCTURE, *supra* note 11, at 22-23.

performance."[141] 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.[142]

From an economic perspective, it makes sense to manage certain infrastructure resources as a commons because doing so permits a wide range of downstream producers of private, public, and non-market goods to flourish. As Professor Yochai Benkler notes, "[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."[143] The point is not that all infrastructure resources (traditional or nontraditional) should be managed as a commons regime. Rather, for certain classes of resources, the economic arguments for managing the resources as a commons 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, the economic arguments for managing an infrastructure resource as a commons vary by type and are stronger for the latter two types.[144] For commercial infrastructure, the arguments are largely grounded in concerns over 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 subsidies.

2. An Infrastructure Typology

To better understand and evaluate these complex economic relationships, I define three general categories of infrastructure resources based on the nature of the distribution of downstream activities: commercial, public and social infrastructure.

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[141] Committee on Measuring and Improving Infrastructure Performance, in its report MEASURING AND IMPROVING INFRASTRUCTURE PERFORMANCE 5 (1995).

[142] The difficulty in assessing social demand for the infrastructure resource is experienced in traditional infrastructure industries. CORNES & SANDLER, *supra* note 26.

[143] Benkler, CORE COMMON INFRASTRUCTURE, *supra* note 11, at 47-48.

[144] *See infra* Part II.D (explaining the various economic arguments for managing each type of infrastructure resources as a commons).

Type	Definition	Examples
COMMERCIAL INFRASTRUCTURE	Nonrival (or potentially nonrival) input into the production of a wide variance of private goods.	1. Basic manufacturing processes 2. Cable television 3. Internet 4. Road systems
PUBLIC INFRASTRUCTURE	Nonrival (or potentially nonrival) input into the production of a wide variance of public goods.	1. Basic research 2. Ideas 3. Internet
SOCIAL INFRASTRUCTURE	Nonrival (or potentially nonrival) input into the production of a wide variance of non-market goods.[145]	1. Lakes 2. Internet 3. Road 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.[146] For example, the Internet is a combination of all three types of infrastructure, as explored in Part IV. I will refer to such infrastructure resources as "mixed" and to infrastructure resources that fall within only one category as "pure." The analytical advantage of this general categorization schema is that it provides a means for understanding the social value generated by these infrastructure resources and identifying different types of market failures.

i. Commercial infrastructure

Commercial infrastructure resources are used to produce private goods.[147] Consider the examples listed in the chart. Basic 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. Basic agricultural processes and food processing techniques similarly are nonrival inputs into the production of a wide variety of private agricultural goods and foodstuffs. Many

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

[146] Consider a basic chemical process as another example. If one invents a generic process for separating mixed chemicals, that process may be used to produce a wide range of private goods (chemicals), public goods (further research into new, improved processes), and non-market goods (learning).

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

commercial infrastructure resources are used productively by suppliers purely as a delivery mechanism for manufactured goods, agricultural goods, foodstuffs, and many other commercial products. 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. The Internet and road systems similarly are used by a wide range of suppliers to delivery 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,[148] (2) market actors (input suppliers) will process this information and (3) satisfy the demand efficiently.[149] Simply put, for commercial infrastructure, output producers should fully appropriate the benefits of the outputs (via sales to consumers) and thus should 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

[148] It may even be the case that even commercial infrastructure may run into a similar type of demand-side market failure as discussed below with respect to public and social infrastructure. Consumer surplus is the portion of the value created by the outputs that is not captured by the output producers. If (1) access is prioritized (due to capacity constraints, for example) 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). I thank Mark Lemley for raising this issue. While interesting, I leave firther consideration for future work. Lemley explores the issue in Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27, at 32 ("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.").

[149] With respect to the third point regarding supply of commercial infrastructure, 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 that debate concern incentives, the presence of natural monopolies, strategic behavior by monopolists (infrastructure providers), and the effectiveness of government institutions, and generally focus on supply-side issues without challenging the first two points made above.

consumers. Competition is the linchpin in this context because the consumptive demands of the public can best be assessed and satisfied by competitive markets.

The first two points noted above underlie one of the famous arguments made by Ronald Coase in *The Marginal Cost Controversy*.[150] Coase argued that governments should not subsidize public access to utilities (natural monopolies) with an aim towards keeping prices charged consumers at marginal cost because doing so would distort the market and disrupt its ability to generate and process individual demand information.[151] I agree with Coase on this point as it pertains to commercial infrastructure. As I will discuss below, the argument does not apply with equal force to public and social infrastructure. First, social and individual demand for access to the infrastructure will diverge to the extent that individuals are unable to appropriate the full value of outputs they generate.[152] Second, managing the infrastructure resource as a commons does not preclude market or government provision but does avoid relying on either the pricing system or the government to assess demand on an *individualized* basis, which is precisely the advantage of a commons regime. For infrastructure managed as a commons, demand is assessed more crudely on a group, community, or societal basis.[153]

Not surprisingly, when we are talking about open access to commercial infrastructure, we are in the familiar territory of antitrust, regulated markets, and commons-like management principles of common carrier and essential facilities doctrine.[154] Historically, common carrier obligations were said to arise in markets

[150] *See* R.H. Coase, *The Marginal Cost Controversy*, 13 ECONOMICA 169-182 (1946); R.H. Coase, *The Marginal Cost Controversy: Some Further Comments*, 14 ECONOMICA 150-153 (1947).

[151] Coase, *The Marginal Cost Controversy*, *supra* note 150, at 176; *c.f.* J.M. Buchanan, *An Economic Theory of Clubs*, 32 ECONOMICA 1 (1965) (making a similar demand-side argument with respect to investing in capacity beyond the point of congestion for club goods).

[152] *See infra*.

[153] *See* H. Hotelling, *The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates*, ECONOMETRICA 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, *Marginal Cost Controversy*, *supra* note 150, at 175).

[154] For a discussion of the history and role of common carrier obligations on infrastructure providers, see Cooper, *Making the Network Connection*, *supra* note 21, at 5. Cooper also argues that these principles should extent to the Internet. *See id.*

"affected with the public interest."[155] 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).[156]

One of the insights that flows from this infrastructure model is that these regulatory principles are applied to a special case or a subset of a much broader phenomenon. First, there is a wider range of resources that are "affected with the public interest" and 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/applications of an infrastructure resource include the production of public goods and non-market goods, the case for common carrier regulation may be even stronger. Mark Cooper states the argument nicely:

> 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."[157]

ii. 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, and thus it is 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

[155] *See* RICHARD EPSTEIN, PRINCIPLES FOR A FREE SOCIETY: RECONCILING INDIVIDUAL LIBERTY WITH THE COMMON GOOD, ch. 10 (1998) (history of common carrier regulation); Walter H. Hamilton, *Affection with Public Interest*, YALE L.J. (1930); *c.f.* Rose, *The Comedy of the Commons*, *supra* note 20 (discussing inherently public property).

[156] EPSTEIN, *supra* note 155, ch. 10.

[157] Cooper, *Making the Network Connection*, *supra* note 21, at 17.

nonrivalrously consumed, and impure public goods are potentially (non)rivalrously consumed.[158] Two points made in the last section bear repeating.

First, the publicness/privateness of a resource is a function of (non)rivalry—how its capacity adjusts to consumption.[159] 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 potentially (non)rivalrously consumed and can be labeled an impure public good.

Second, the publicness/privateness of a resource is not a function of excludability.[160] Excludability refers to how costly it 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.

Public goods (pure and impure) and private goods are supplied by the market mechanism with varying degrees of effectiveness. For private goods, the market mechanism generally works very well from the 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

[158] *See supra* Part II.A.
[159] *See supra* Part II.A.
[160] *See supra* note 98 (discussing Demsetz). Some analysts view public goods narrowly in terms of a supposed market failure that occurs because consumers in particular fail to contribute their optimal/fair share. *See, e.g.*, CORNES & SANDLER, *supra* note 26 (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 (bads). Specifically, I view public goods (bads) more generally as resources that have the *potential* to generate positive (negative) externalities, depending upon how access to the resources are managed. *C.f.* Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. PAPERS & PROC. 347, 348 (1967) ("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 into will depend on the institutional setting and overall context.

exclusion and thereby provide improved incentives to invest in supplying the desired public good.

"Non-market goods" refer to those goods that are neither provided nor demanded through the market mechanism; we do not "purchase" such goods.[161] We may recognize the value of such goods but we simply do not rely on the market as a provisional mechanism. Instead, we rely on other provisional mechanisms, involving government, community, family, and individuals.

Consider, for example, the preservation of certain resources, perhaps historic or environmental, for generations in the distant future. It may very well be the case that society as a whole considers such an objective to be worthwhile, but for various reasons not worth explaining 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; redistribution of wealth to aid those in need, etc. Many of the things we strongly value in the United States as a public are non-market goods.[162]

From the demand-side, the important distinction between these outputs—what separates non-market 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 appreciates 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 whether the producer internalizes the full 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

[161] *See* Nicholas E. Flores, *Conceptual Framework for Nonmarket Valuation*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 37, at 27.

[162] *C.f.* Cohen, *Perfect* Curve, *supra* note 41, at 1808-1810 (2000); CORNES & SANDLER, *supra* note 26, at 51 (discussing "environmental commodities"). There is some similarity between non-market goods and merit goods. While non-market goods are not provided for by the market, merit goods are partially provided by the market. Merit goods are considered so beneficial to the public that any deficiency in market provision will be made up for with public provision. 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 did not have the necessary skills to become productive members of society. Therefore, education is a good whose social merit has been recognized, and is therefore often provided by both the public and private sectors to insure more widespread consumption. RICHARD A. MUSGRAVE, THE THEORY OF PUBLIC FINANCE, 13-14 (1959).

realized by those who walk by and appreciate their beauty. The view of the flowers is nonrival in the sense that consumption by one person does not deplete the view (or beauty) available for other to consume. Consumption depends upon access, however, and whether the potential externalities are realized depends upon whether the homeowner builds an effective fence (*i.e.*, one that would obstruct the view from the sidewalk). If the homeowner does build an effective fence, then the door has been closed and the potential for externalities remains untapped potential. 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,[163] although some would use derogatory, loaded labels such as "free-riders" or even "pirates."[164] 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.[165] 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.[166]

By contrast, the value of non-market goods is realized in a more osmotic fashion and not through direct consumption. Non-market goods change environmental conditions and social interdependencies in ways that increase social welfare.[167] Take, for example, active participation in democratic dialogue or education. While participants may realize direct benefits as a result of their activity, non-participants (non-consumers) 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 affect 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 election benefit participants as well as those persons that never log onto the Internet.[168]

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[163] CORNES & SANDLER, *supra* note 26, at 55 ("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.").

[164] *See* LESSIG, FREE CULTURE, *supra* note 60 (discussing such labels); Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27 (same).

[165] *See id*. at 19-20, 22-23.

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

[167] CORNES & SANDLER, *supra* note 26, at 51.

[168] *See infra* Part IV. *See also infra* Part III.A (discussing how a family fishing trip may generate non-market goods such as family values).

To sum up, the production of public goods has the potential to generate positive externalities for non-paying consumers (incidental beneficiaries or free-riders), and the production of non-market goods generates diffuse positive externalities, often realized by non-participants or non-consumers.

iii. Public and social infrastructure: Understanding the demand-side analysis

Public and social infrastructure resources are used to produce public goods and nonmarket goods respectively.[169] For much of the analysis that follows, I have grouped 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 information 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 non-market 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.[170]

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[169] I discuss examples throughout Parts III and IV.

[170] I say (potential) benefits to remind the reader that once created, public ggoods have the potential to generate positive externalities. In addition, it bears emphasizing that the inability to fully appropriate the (potential) benefits of public goods and non-market goods in not remedied by full excludability. As noted in the previous section, exclusion facilitates conditioning access to something upon payment. But absent perfect price discrimination, whereby sellers can match the price of their goods to each consumer's willingness to pay, the full range of potential benefits will not be realized or appropriated because some consumers will be priced out. Perfect price discrimination typically is not feasible in the real world, however. Nicholas Economides, *The Economics of Networks*, 14 INT'L J. INDUSTRIAL ORG. 11 (1996) ("Clearly, the welfare maximizing solution can be implemented through perfect price discrimination, but typically such discrimination is unfeasible"). Further, there are a host of distributional and efficiency issues that remain even with perfect price discrimination. Such issues are beyond the scope of this article. In a separate paper, I address perfect price discrimination and imperfect price discrimination and the how the path to perfect price discrimination itself may be risky because of the likelihood that investments, technological design, and even the law can be optimized along the way in favor of commercial outputs. The constant pull of market forces exerts tremendous pressure on infrastructure providers and government to direct investments in capacity expansion, technological upgrades to the infrastructure, and research and development toward commercial ends. *See infra*

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."[171] 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, through the twin powers of prices and incentives, will not [fully] take into account (or provide the services for) the broader set of social benefits attributable to the public goods[, non-market 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].[172]

Difficulties in measuring and appropriating value generated in output markets thus translates in a valuation/measurement problem for infrastructure suppliers.[173] As Yochai Benkler has emphasized, output producers are not always seeking 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 upon access to the infrastructure but not for the immediate purpose of creating appropriable benefits.[174] 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.[175]

To make matters even more complicated, for some, though not all, infrastructure resources, and particularly those that act as inputs into cumulative

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Part IV. Further, as Lessig argues in Free Culture, the legal environment supporting infrastructure provision may also be optimized in a manner that favors commercial interests. *See infra* note 304.

[171] Frischmann, *Internet Infrastructure*, *supra* note 36, at 51. *See also* LANDES & POSNER, THE POLITICAL ECONOMY OF INTELLECTUAL PROPERTY LAW, *supra* note 60 ("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.").

[172] Frischmann, *Internet Infrastructure*, *supra* note 36, at 66.

[173] For illustration by example, see *infra* Part III.A (lake example).

[174] *See* Benkler, *Coase's Penguin*, *supra* note 13; Benkler, *Freedom in the Commons*, *supra* note 12; Benkler, *The Political Economy of Commons*, *supra* note 50.

[175] *See* Benkler, *Coase's Penguin*, *supra* note 13; Benkler, *Freedom in the Commons*, *supra* note 12.

production processes, there may be considerable uncertainty as to what types of downstream applications may arise in the future.[176] Prospective uncertainty can exist along various dimensions that affect investment and management decisions.[177] Such uncertainty complicates decision making and raises transaction costs (*e.g.,* costs associated with identifying and dealing with future contingencies). Moreover, market actors may be averse to uncertainty itself.[178]

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.

C. Network effects

Most, if not all, traditional infrastructure resources are networks.[179] Economists have devoted substantial effort in recent years seeking to unravel the peculiar economic features of networks, commonly referred to as "network effects."[180] Interestingly, much like the analysis in this article with respect to infrastructure, network economists realized that many non-network industries

[176] For illustration by example, see *infra* Part III.B (basic research example).

[177] *See, e.g.*, Frischmann, *Innovation and Institutions*, *supra* note 32, at 362, 366-67, 374-75 & n.104; Scotchmer, *Standing on the Shoulders of Giants*, *supra* note 89 (uncertainty makes ex ante contracting between input suppliers and output producers difficult); Nicholas E. Flores, *Conceptual Framework for Nonmarket Valuation*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 37, at 27, 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 argument from J.V. Krutilla, *Conservation Reconsidered*, 57 AMERICAN ECONOMIC REVIEW 777 (1967)).

[178] *See* Frischmann, *Innovation and Institutions*, *supra* note 32 at 375, n.109 (citing to studies).

[179] *See* Economides, *The Economics of Networks*, *supra* note 170, at 673 ("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 ""Often (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, and thus enables the realization of the network effects, is called a *network*." Amitai Aviram, *A Network Effects Analysis of Private Ordering*, Berkeley Olin Program in Law & Economics, Working Paper Series 11079, Berkeley Olin Program in Law & Economics (2003). Traditional infrastructure resources often act as such a network.

[180] *See id*. *See generally* Nicholas Economides, *Network Externalities, Complementarities, and Invitations to Enter*, 12 EUR. J. POL. ECON. 211, 213 (1996).

exhibited network effects and have extended their analysis accordingly.[181] Nicholas Economides, a pioneering network economist, provides the following simple 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, the network components are complementary to each other.[182]

Network effects are demand side effects that often, although not always, result in positive externalities (generally referred to as network externalities).[183] 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 (specifically, to produce functionally compatible goods).[184] 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 explain:

> [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

[181] Economides, *The Economics of Networks*, *supra* note 170, at 673.

[182] Nicholas Economides, *Competition Policy in Network Industries: An Introduction*, *in* THE NEW ECONOMY: JUST HOW NEW IS IT (Dennis Jansen ed., 2003)..

[183] Michael L. Katz & Carl Shapiro, *Systems Competition and Network Effects*, J. Econ. Persp., at 93, 96-100 (Spring 1994); Michael L. Katz & Carl Shapiro, *Network Externalities, Competition, and Compatibility*, 75 AM. ECON. REV. 424, 436 (1985). Economists often define network effects as "increasing return to scale in consumption." Economides, *Competition Policy in Network Industries*, *supra* note 183, at 5.

[184] *See* Lemley & McGowan, *Legal Implications of Network Economic Effects*, *supra* note 47, at 488-494; Economides, *Competition Policy in Network Industries*, *supra* note 183, 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.").

> infrastructure is capable of processing all member communications reliably.[185]

As Carol Rose commented, "the more the merrier."[186]

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.[187] "Computer software is the paradigm example."[188] 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),[189] and from vertical interoperability, as in the case of operating systems and application programs (*e.g.,* Microsoft Windows and word processing software).[190] As Mark Lemley and David McGowan explain:

> [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

[185] Lemley & McGowan, *Legal Implications of Network Economic Effects*, *supra* note 47, at 488-89.

[186] Rose, *The Comedy of the Commons*, *supra* note 20, at 768. Congestion may act as a significant constraint. *See* Amitai Aviram, *A Network Effects Analysis of Private Ordering*, Berkeley Olin Program in Law & Economics, Working Paper Series 11079, Berkeley Olin Program in Law & Economics (2003).

> Congestion is a major limit on efficient scales in rivalrous networks (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. Non-rivalrous networks, such as languages, PC or video cassette standards, etc., do not suffer from congestion (e.g., 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.; Lemley & McGowan, *Legal Implications of Network Economic Effects*, *supra* note 47, at 497.

[187] Economides, *Competition Policy in Network Industries*, *supra* note 183, at 5.

[188] Lemley & McGowan, *Legal Implications of Network Economic Effects*, *supra* note 47, at 491.

[189] *Id.*

[190] *See* Phillip J. Weiser, *The Internet, Innovation, and Intellectual Property Policy*, 103 COLUM. L. REV. 534 (2003)

> 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 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, ...[191]

Nicholas Economides notes that the "key reason for the appearance of network externalities is the complementarity between network components."[192] The essential difference between direct and indirect effects is whether "customers are identified with components," in which case the effect is direct.[193]

Although network effects (of both types) 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 non-market goods by end-users that obtain access to the infrastructure resource and use it as an input.[194]

There is a critical difference between network effects and "infrastructure effects"[195] and the resulting types of externalities. Network effects tend to increase consumers' willingness to pay for access to the resource.[196] By definition, network effects arise when users' utilities increase with the number of other users. Economists assume that consumers appreciate the value created by

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[191] Lemley & McGowan, *Legal Implications of Network Economic Effects, supra* note 47, at 491-92 (footnote omitted). Lemley & McGowan discuss other examples of virtual networks. *Id.* at 491-94.

[192] Economides, *Competition Policy in Network Industries*, *supra* note 183, at 6.

[193] *Id.* at 6.

[194] *See supra* Part II.B.

[195] I hesitate to use this term because it very difficult to isolate a narrow definition. For now, "infrastructure effects" is used to refer to "comedy of the commons" type situations where open access to a resource generates positive effects (externalities) through the production of public goods and non-market goods.

[196] Economides, *The Economics of Networks*, *supra* note 170, at 684; Economides, *Competition Policy in Network Industries*, *supra* note 183, at 6.

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.[197] 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,"[198] 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.[199]

[insert graph 1 (S-D illustrating law of demand)]

[insert graph 2 (S-D illustrating network effect; make it additive so that you can see the upward pull of the extra value created by the network effect)]

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 the 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 wider variance) of applications may lead to an increase in consumers' valuation of the infrastructure or network, but the externalities generated by public and social infrastructure are even more indirect in that they are diffuse, derived from public and non-market 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

[197] *See id.* at11; Spulber & Yoo, *Access to Networks*, *supra* note 37, at 926 ("The economic literature indicates that regulation of network externalities is unnecessary, because private ordering can easily resolve economic problems that may arise. Any network externalities that may exist in the examples upon which we are focusing will necessarily occur within a physical network that can be owned. Thus, although individual users may not be in a position to capture all of the benefits created by their demand for network services, the network owner will almost certainly be in a position to do so. With a single network owner, the problems associated with this type of externality can be solved in the same manner as externality problems in other contexts--by placing property in the hands of a single owner and protecting it with well-defined property rights. Benefits created by network participation can thus be internalized and allocated through the interaction between the network owner and network users.") (footnotes omitted).

[198] Nicholas Economides, *Network Externalities, Complementarities, and Invitations to Enter*, 12 EUROPEAN JOURNAL OF POLITICAL ECONOMY 211, 213 (1996); Economides, *Competition Policy in Network Industries*, *supra* note 183, at 6.

[199] *Id.* at 6; Economides, *The Economics of Networks*, *supra* note 170, at 682.

often positively affect the utility of non-users, that is, members of society that are not using the infrastructure itself.[200] 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,[201] making the possibility of a demand-side market failure much more likely.

[insert graph 3 (S-D illustrating infrastructure effect without network effects; thus, graph 1 with private and social demand curves; social demand curve is pulled upward due to added social surplus from the production of a public/non-market good)]

D. The Case for Infrastructure Commons

To 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 that infrastructure resources generate value when used as inputs into a wide range of productive processes and that the outputs from these processes are often public goods and nonmarket goods that generate positive externalities that benefit society as a whole. Managing such resources as a commons may be socially desirable when doing so takes advantage of nonrivalry and facilitates these types of downstream activities.[202]

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

[201] On the theory of "internalizing complementary externalities" or "ICE," see Farrell & Weiser, *Modularity, Vertical Integration, and Open Access Policies*, *supra* note 6.

[202] Benkler explores the possibility of managing nonrival and potentially nonrival inputs as a commons. *See* Benkler, *The Commons As A Neglected Factor of Information Policy*, *supra* note 5 (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*; *see also* Yochai Benkler, *Some Economics of Wireless Communications*, 16 HARV. J. L. & TECH. 25, 79 (Fall 2002); Benkler, *Overcoming Agoraphobia*, *supra* note 12, at 361-362. More generally, Yochai Benkler has explored the advantages of commons-based information production. *See, e.g.*, Benkler, *Coase's Penguin*, *supra* note 13; Benkler, *From Consumers to Users*, *supra* note 13.

The case for commons management must be evaluated carefully and contextually. Broad prescriptions are not easily derived. To facilitate analysis, I developed an infrastructure typology to distinguish between commercial, public and social infrastructure, based upon the nature of outputs and the potential for positive externalities. In this section, I set forth the economic arguments for managing these different types of infrastructure as commons.

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.[203] 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.[204]

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 good or non-market 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.[205]

For purposes of illustration, let us engage in a brief thought experiment. For each infrastructure type, we will (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

[203] *See supra* Part II.B. *See* Farrell & Weiser, *Modularity, Vertical Integration, and Open Access Policies*, *supra* note 6; Philip J. Weiser, *Toward A Next Generation Regulatory Regime*, 35 LOY. U. CHI. L. REV. 41, 74-84 (2003).

[204] *See supra* note (discussing natural monopolies).

[205] These points reflect well-understood concepts underlying traditional public goods market failure analysis.

public and social infrastructure, the rankings likely are quite different because there may be many low willingness to pay users/uses that generate great social value (much of which is externalized).[206]

Social surplus (*i.e.*, the amount by which the social value exceeds the private value) may result from a "killer app," such as email or the World Wide Web, that generates significant positive externalities or from a large number of outputs that 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 (or undervalued) by most analysts.[207] Yet in both cases, there may be a strong argument for managing the infrastructure resource as a commons to facilitate these productive activities.

The social costs of restricting access to public or social infrastructure can be significant and yet evade observation or consideration within conventional economic transactions. Initially, we may analyze the issue as one of high transaction costs and imperfect information; yet even with perfect information and low/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.[208] If we rely on the market as the

[206] *See* charts 1-3 from appendix. **Note to reviewers:** In the appendix, I have included a few charts that I use when presenting this paper orally. While audience members have found them quite helpful, I have not decided whether to include them in the final publication. With this understanding, I include them in this submission for your review.

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

[208] 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 openness/restrictiveness of access to the infrastructure and the related terms of access can be thought of as a definitional characteristic 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

provisional 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.[209] 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 transactions cost problems that may hamper markets.[210] For example, transaction costs associated with price setting, licensing, and enforcement (may) increase as the variance of public good and non-market good outputs increases.[211]

Economists recognize that there is a case for subsidizing public and nonmarket goods producers because such goods are undersupplied by the

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neutrality 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 or non-commercial ends or at no particular ends at all. 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* Frischmann, *Innovation and Institutions*, *supra* note 32, at 406-07; Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77, 109-13 (1999); Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 291 (2003); J.H. Reichman & Paul F. Uhlir, *A Contractually Reconstructed Research Commons for Scientific Data in a Highly Protectionist Intellectual Property Environment*, 66 LAW & CONTEMPORARY PROBLEMS 315-440 (2003); *see also* Robert P. Merges, *Property Rights Theory and the Commons: The Case of Scientific Research*, *in* SCIENTIFIC INNOVATION, PHILOSOPHY, AND PUBLIC POLICY 145 (Eds. Ellen Frankel Paul et al. 1996). *C.f.* WIL LANDES & POSNER, THE POLITICAL ECONOMY OF INTELLECTUAL PROPERTY LAW, *supra* note 60, at 15-17 (illustrating through public choice analysis how copyright law itself may be biased toward appropriable benefits).

[209] I discuss this bias below. *See infra* Part III; *see also* Benkler, *Freedom in the Commons*, *supra* note 12 (discussing various market biases).

[210] *See, e.g.*, Arti 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 (2004); Gregory Tassey, *Infratechnologies and Economic Growth*, *in* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 59, 71 (Teubal et al., eds. 1996). For an interesting paper on transaction costs, see Driesen & Ghosh, *The Functions of Transaction Costs*, *supra* note 68, at 31 (defining transaction costs broadly as "the costs of dealing with people" and arguing that transaction cost serve various positive functions).

[211] CORNES & SANDLER, *supra* note 26, ch. 4 (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).

market.[212] 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,[213] but it does eliminate the need to rely on either the market or the government to "pick winners"[214] (or uses worthy of access).[215] 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.[216] On the other hand, in order 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).[217] As illustrated below with some examples, the inefficiencies, information problems and transaction costs associated with picking winners under either system may justify managing public and social infrastructure resources as commons.

[E. section on price discrimination – to be inserted

Before proceeding, a brief word on price discrimination. Perfect price discrimination should eliminate many of the demand-side concerns I have raised because, by definition, perfect price discrimination means that all consumers who desire access are granted access at their respective willingness to pay.[218] Perfect price discrimination typically is not feasible in the real world, however.[219]

[212] *See* CORNES & SANDLER, *supra* note 26.

[213] Open access may operate as the functional equivalent of a subsidy, depending upon the context.

[214] I thank Lauren Gelman of the Stanford Law School Center for Internet & Society for focusing my attention on the notion of "picking winners."

[215] Larry Lessig has emphasized that commons avoids relying on market incumbents to decide the future of innovation, and Yochai Benkler has emphasized that commons avoids relying on the market (and property rights holders) more generally. *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 14 and Benkler, *The Political Economy of Commons*, *supra* note 50.

[216] *See supra* Part II.B-D (discussing this dynamic).

[217] *See* Frischmann, *Innovation and Institutions*, *supra* note 32 at 386-91 (discussing government assessment of demand for public goods).

[218] **Cite to definition**

[219] Nicholas Economides, *The Economics of Networks*, 14 INT'L J. INDUSTRIAL ORG. **[pages – pinpoint cite to page 11 of text]** (March 1996) ("Clearly, the welfare maximizing solution can be

Further, there are a host of distributional and efficiency issues that remain even with perfect price discrimination.[220] Nonetheless, since perfect price discrimination may be available in particular contexts, it ought to be compared with a commons regime on a case by case basis. Such a comparison, and discussion of imperfect price discrimination will be discussed briefly in this section.

- expand discussion
- explore how attractiveness of imperfect price discrimination varies by infrastructure type
- perhaps explore the "path to perfect price discrimination" and how the infrastructure can be altered along the way (*e.g.*, Internet infrastructure or copyright law itself)]

III. ILLUSTRATIVE EXAMPLES: ENVIRONMENT AND INFORMATION

To provide a bit more context to what may seem like an abstract economic theory, I discuss a few descriptive examples of nontraditional infrastructure resources in this Part. 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 influential article, *A Politics of Intellectual Property: Environmentalism for the Net?*, Jamie Boyle argued that "we need a politics, or perhaps a political economy, of intellectual property," modeled after the environmental movement.[221] Boyle articulated his vision of an information or public domain movement 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.[222]

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implemented through perfect price discrimination, but typically such discrimination is unfeasible").

[220] *See* [cites].

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

[222] *Id.*

Scholars have begun the process of "borrowing" from the environmental movement,[223] but the borrowing in mainly founded on rhetorical or descriptive metaphors and analogies (for example, commons, information ecosystems, etc.). While such analysis is a useful starting point, analytic comparison of both resource problems and solutions is lacking. This article take 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 of descriptive metaphor, but rather of normative principles, such as precautionary principle, intergenerational equity, and sustainable development, that 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.

The infrastructure theory developed in this article builds a substantive bridge between these disciplines that is grounded in economics. Building this bridge is important because it provides a foundation for mapping normative principles across disciplines. In this article, I focus on the principle of managing fundamental resources as commons.

There are very interesting parallels between environmental and information infrastructure resources in that 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 as commons is critical to realizing this potential.

A. Environment as infrastructure

At a very general level, the environment as a whole can be viewed as natural infrastructure that is an essential input into a wide range of human and

[223] *See id.* (intellectual resources); Boyle, *Second Enclosure Movement*, *supra* note 89 (same); Benkler, *Battle Over the Institutional Ecosystem*, *supra* note 13 (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 back and forth between the environment, information, and the Internet areas, see Jim Chen, *Webs of Life: Biodiversity Conservation as a Species of Information Policy*, 89 IOWA L. REV. 495 (2004); *Conference, Intellectual Property, Sustainable Development, and Endangered Species: Understanding the Dynamics of the Information Ecosystems*, Michigan State University-DCL College of Law, March 2004. *See* http://www.law.msu.edu/ipclp/conference04/index.html.

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."[224] It also provides service flows essential to natural processes, including a wide variety of ecosystem services such as "purification of air and water, detoxification and decomposition of wastes, regulation of climate, regeneration of soil fertility, and production and maintenance of biodiversity."[225] Revesz and 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."[226]

While viewing the environment from bird's eye perspective is appealing, it is helpful to focus more acutely on specific environmental resources. Consider a lake. What makes a lake valuable to society? Like a road system, a lake is socially valuable primarily because of what it facilitates downstream, how it can be used to produce social benefits. Think about the wide variety of uses of many lakes: Fishing, boating, swimming, other recreational activities, use as subject matter for artwork, commerce, transport of goods, sink for pollution, waste processing, drinking water source, etc., not to mention the socially valuable role of the lake in supporting a complex ecosystem.[227] We could go on for some time.

A lake satisfies all three criteria. It may be consumed (non)rivalrously; downstream uses drive social demand for (access to) the lake; and the range of goods and services produced downstream varies considerably across the spectrum of public, private and non-market goods. Some of these uses are purely consumptive and some are competing, for example, too much pollution may

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[224] Richard L. Revesz & Robert N. Stavins, *Environmental Law and Policy*, draft at 8-9 (available on SSRN.com) (forthcoming in THE HANDBOOK OF LAW AND ECONOMICS).

[225] Gretchen C. Daily et al., *Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems*, 2 Issues in Ecology 1 (1997), 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 37, at 1, 3 (listing the following examples: "nutrient recycling, organic material decomposition, soil fertility generation and renewal, crop and natural vegetation pollination, and biological control of agricultural pests").

[226] Revesz & Stavins, *Environmental Law and Policy*, *supra* note 221, at 9.

[227] On the wide variety of socially valuable uses of environmental resources, see A PRIMER ON NONMARKET VALUATION, *supra* note 37.

preclude swimming or ruin the view.[228] Thus, a lake is a potentially (non)rival good that *may be* consumed nonrivalrously, depending upon how it is managed. We can look at the issue of competing uses from the opposite perspective and focus on the fact that downstream uses are potentially rivalrous (as opposed to potentially nonrivalrous). From either perspective, it is critical to realize that rivalry (or nonrivalry) is not a preordained fact.[229] In deciding how to manage a potentially (non)rival good and deal with the 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 very difficult to estimate the social value of a lake, in large part because of the wide variety of downstream uses that generate public and non-market goods.[230] Economists have developed various methods for approximating the value of environmental resources, such as "stated preference methods" and "revealed preference methods."[231] While these methods have advanced significantly in the past few decades[232] and are increasingly used in policy and resource management settings,[233] such methods are (at best) useful but incomplete proxies for measuring

[228] The fact that there are competing uses of a resource with finite capacity means that we are dealing with scarcity and trade-offs. *See* A. Myrick Freeman III, *Economic Valuation: What and Why*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 37, at 1-3.

[229] As noted in Part II.A, whether or not consumption of a potentially (non)rival resource turns rivalrous depends upon 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. *See supra*.

[230] *See generally* A PRIMER ON NONMARKET VALUATION, *supra* note 37. As discussed at length by Carol Rose, courts have recognized both the existence of multiple uses of waterways and bodies of waters (recreation, commercial travel, fishing, transport, etc.) 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 20. 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 led to increased social returns (referred to as scale returns). *See id*.

[231] *See* A PRIMER ON NONMARKET VALUATION, *supra* note 37. 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, *Environmental Law and Policy*, *supra* note 221, at 12-20 (providing an accessible account of these and other methods).

[232] *See generally id*.

[233] *See* Daniel W. McCollum, *Nonmarket Valuation in Action*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 37, at 483-531.

the social value of environmental resources.[234] As James Salzman and J.B. Ruhl observe, "environmental law relies almost entirely on proxy measures."[235]

The potentially nonrival nature (or conversely, the potentially 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.[236] This is a very important demand-side dilemma.[237] 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 way. Lakes are products of nature, and thus we need not worry about producing lakes per se. It is well-recognized that lakes present a consumption problem, however, 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."[238] As Revesz and Stavins remind us,

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[234] *See* Richard C. Bishop, *Where to From Here?*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 37, at 537, 539 ("[T]rue economic values are unobservable."); Revesz & Stavins, *Environmental Law and Policy*, *supra* note 221, 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*. 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.").

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

[236] *See generally* Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

[237] 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.

[238] A. Myrick Freeman III, *Economic Valuation: What and Why*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 37, at 1, 3.

we live in a world of finite resources and thus must take into account trade-offs between social investments.

> 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.[239]

Recognizing that lakes create social value primarily when they are used as inputs into the production of a wide variety of outputs suggests that in evaluating these tradeoffs, we need to pay attention to the nature of those outputs. To the extent that public goods and non-market 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.[240]

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 non-market goods. As the capacity of lakes is finite and cannot be expanded (like some other potentially nonrival resources that also present a similar set of tradeoffs), these competing potentialities give rise to a tradeoff between open and restricted access to the resource that must be reconciled.[241] How is this tradeoff reconciled? Can (or should) an infrastructure commons be sustained in this context?

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[239] Revesz & Stavins, *Environmental Law and Policy*, *supra* note 221, at 3-6.

[240] *See id*. 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").

[241] *C.f.* Bell & Parchomovsky, *Of Property and Antiproperty*, *supra* note 114 (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 "a very different problem" 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." Still, depending upon one's perspective, conservation may be viewed as a use that (1) preserves unimpeded access to the resource for non-

The dominant regulatory approach in the environmental area targets particular consumptive uses of an environmental resource and limits consumption to sustainable levels (at least in theory with the appropriate information),[242] while at the same time (and this is the key) 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 open as a commons for recreational and other community uses. This does not mean that no pollution is allowed. Rather, it means that pollution of various types is regulated in a manner that sustains access to the resource for other non-polluting uses.[243]

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.[244] 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 handle but beyond the range that causes harm to swimmers—humans and fish). It is tempting to presume that the owner has internalized all the costs and benefits associated with his or her decisions, and thus conclude that the decision maximizes social welfare.[245] Such reasoning is faulty, however. The lost benefits to recreational users may exceed the marginal

consumptive uses that also 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 (1) the other users and/or (2) future generations. *C.f. id.* at 6 n.23 (suggesting that anticommons regimes used to sustain parks and open space yield positive externalities for adjacent private property owners).

[242] 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, *Environmental Law and Policy*, *supra* note 221, at 31-54; David Driesen, *The Economic Dynamics of Environmental Law:Cost Benefit Analysis, Emissions Trading, and Priority-Setting*, 31 B.C. ENVTL. AFF. L. REV. 501 (2004).

[243] 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 and sustain a commons for other uses.

[244] The prospect of reaching an optimal outcome through bargaining among potential users is doubtful because we live in a world of limited information and transaction costs. *See* R.H. Coase, *The Problem of Social Cost*, 3 J. L. & ECON. 1 (1960).

[245] *See generally* Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. PAPERS & PROC. 347, 348, 349 (1967) ("A primary function of property rights is that of guiding incentives to achieve a greater internalization of externalities.").

benefits of additional pollution, but the latter may be more easily appropriable than the former. There may be a wide variance of downstream uses of a lake that are excluded from consideration by the property owner 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. Imagine further how difficult it would be to manage access to the lake.[246] 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 the much larger number of small-scale commercial and non-commercial users.[247]

Difficulties in appropriation may be a function of transaction costs associated with "dealing" with a wide variety of different types of users.[248] Such costs may relate to information acquisition and exchange,[249] negotiating and enforcing commitments,[250] demand-side coordination (to resolve collective action problems),[251] 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 out on the lake for a fishing trip, there are external benefits that accrue to society as a whole that are not captured

[246] The underlying information problems faced by a single property owner seeking to maximize his or her own welfare are similar to those faced by a manager of a public resource as well. 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. *C.f.* Thomas C, Brown & George L. Peterson, *Multiple Good Valuation*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 37, at 221, 221 (asking the reader to "[a]ssume for the moment that you are the supervisor of the Roosevelt National Forest" and noting the need to measure and compare the value of multiple downstream goods).

[247] *See* Bell & Parchomovsky, *Of Property and Antiproperty*, *supra* note 114, at 27-28 (discussing the impact of group size and skewed distribution of benefits). 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 adjoining the lake. *Id.*

[248] *See* Driesen & Ghosh, *The Functions of Transaction Costs*, *supra* note 68, at 31.

[249] *See id.* at 34; Daniel Esty, *Environmental Protection in the Digital Age*, 79 N.Y.U. L. REV. 115 (2004).

[250] Driesen & Ghosh, *The Functions of Transaction Costs*, *supra* note 68, at 36.

[251] *See* Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. PAPERS & PROC. 347, 357-59 (1967); MANCUR OLSON, THE LOGIC OF COLLECTIVE ACTION (1971) (seminal work on collective action problems).

or necessarily even appreciated by us (my family); we develop connections with nature and among ourselves, 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 benefits participants directly and nonparticipants (third-parties) indirectly. Consider also a pristine view. While appreciation of the view over Lake Michigan yields direct consumptive benefits that people certainly appreciate and value,[252] it also acts as an input into cultural and social processes that yield, among other things, artwork, literature, memories, and culture.[253]

Difficulties in appropriation also may arise in situations where there are simply no human agents engaged in production downstream; for example, when the socially valuable outputs are products of natural rather human processes.[254] 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.[255]

The market mechanism exhibits a bias for outputs that generate observable and appropriable benefits at the expense of outputs that generate positive externalities.[256] This is not surprising because the whole point of relying on

[252] 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. *See* Bell & Parchomovsky, *Of Property and Antiproperty*, *supra* note 114.

[253] 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.

[254] A. Myrick Freeman III, *Economic Valuation: What and Why*, *in* A PRIMER ON NONMARKET VALUATION, *supra* note 37, at 1, 3 (describing indirect environmental services that support "biological and ecological production processes that yield value to people").

[255] 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.

James Salzman and J.B. Ruhl, *Currencies and the Commodification of Environmental Law*, 53 STAN. L. REV. 607, 612 (2000). *See also* Daniel Esty, *Environmental Protection in the Digital Age*, 79 N.Y.U. L. rev. 115, 162-63 (2004) (discussing the importance of "'see[ing]' environmental problems more clearly").

[256] 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

property rights and the market is to force externalities to be internalized.[257] 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.[258] For instance, because private discount rates tend to be higher than social discount rates, markets tend to be biased towards the short term.[259] Among other things, the divergence between private and social discount rates can lead to overconsumption of environmental resources in the present without due regard to the costs for future generations (as well as 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).[260] Further, incumbent market actors may act strategically to preserve their market positions or control the direction of innovation.[261] These two biases introduce further dynamic complications associated with path dependence and the costs of changing directions once a path has been taken.[262]

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.[263] That being said, most lakes play an integral role in

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market to function. *See* Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27 ("[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 COMM. 635 (1996)).

[257] *See, e.g.*, Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. PAPERS & PROC. 347, 348, 349 (1967); Douglas Lichtman, *Property Rights in Emerging Platform Technologies*, 29 J. OF LEGAL STUD. 615, 617 (2000).

[258] *See* Frischmann, *Innovation and Institutions*, *supra* note 32, at 374-75 (discussing various types of market biases in the context of innovative process market failure).

[259] *See id.*

[260] *See infra* Parts III.B & IV.

[261] LESSIG, THE FUTURE OF IDEAS, *supra* note 7; *see also* Benkler, *Freedom in the Commons*, *supra* note 12 (discussing various market biases).

[262] *See* Lemley & McGowan, *Legal Implications of Network Economic Effects*, *supra* note 47, 597-98.

[263] Compare Lake Michigan, one of the Great Lakes, with Keuka Lake, one of the small Finger Lakes in upstate New York.

supporting natural ecosystems that generate non-market goods, and thus may constitute social infrastructure. In addition, an important point to take from this brief discussion of environmental institutions is 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, at the same time, preserve the open access nature of the commons for other activities.[264]

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. Information as infrastructure

Applying infrastructure theory to information generally delineates a class of intellectual resources that create 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 this definition. Two examples are worth discussing briefly. First, consider the 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

[264] Of course, government regulation alone 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* LESSIG, CODE AND OTHER LAWS OF CYBERSPACE (2000); Henry E. Smith, *Semicommon Property Rights and Scattering in the Open Fields*, 29 J. LEGAL STUD. 131 (2000); Robert Heverly, *The Information Semicommons*, 18 BERKELEY TECH. L.J. 1127 (2003); Bell & Parchomovsky, *Of Property and Antiproperty, supra* note 114 (exploring the use of antiproperty easements awarded to property holders proximate to a resource as a means for conserving the resource).

managed in a way that renders consumption nonrivalrous. What about the *idea of a nail*? Ideas are nonrival, 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).[265] 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, which means that the case for open access is quite weak because competitive output markets should work fine from the demand-side.[266] Second, imagine that scientists discover the cure for a particular disease. While such a 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.

The point of focusing on information that satisfies all three criteria for infrastructure is that doing so helps distinguish different types of information based upon 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 intellectual resources (of all types) involves cumulative processes; we know that some intellectual resources are more generic and basic, and more fundamental to these cumulative processes; and we know that in the "great balancing act" we call intellectual property, not all intellectual resources are or should be treated the same. Yet, despite our knowledge of these facts, our struggle over striking the appropriate balance does not adequately take into account the economic differences between intellectual resources.[267]

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[265] The 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 (discussing ideas and apples).

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

[267] *See* Mike Carroll, *Tailoring Intellectual Property Rights*, Draft paper (2004) (on file with author); Mark A. Lemley & Dan L. Burk, *Policy Levers in Patent Law*, 89 VIRGINIA L. REV. 1575 (2003).

Consider, for example, basic research.[268] 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.[269] It satisfies all three criteria 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 (information, knowledge and learning);

[268] There are many other examples to consider. For example, databases. Is a database infrastructure? Not always, it depends upon 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 with the Charles River Bridge. Raymond Shih Ray Ku, *Copyright, the Constitution & Progress*, Case School of Law, Public Law Research Paper No. 04-8. 5 (June 2004) at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=556642. *See* Charles River Bridge v. Warren Bridge, 36 U.S. (11 Pet.) 420 (1837). 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. (2001) (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 information resources that behave like infrastructure for another paper.

[269] In discussing the value of basic research, I focus primarily focus 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. Let's 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 human utility functions, and it certainly need not be instrumental. Perhaps we can think of the non-instrumental, 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.

and, by definition, there is a wide variance in downstream uses.[270] It is very difficult to estimate the social value of basic research, in large part 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.[271] Nonetheless, as with many traditional infrastructure, it is well-recognized that basic research contributes significantly to economic growth and social welfare.[272]

The nonrival nature of basic research itself is only part of the puzzle, although an important part. As noted in the previous section, nonrival resources have infinite capacity and thus do not face the consumption problem.[273] Information resources face the well-known supply-side problem that 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 *may* lead to undersupply.[274] The frequently told free-rider story focuses our attention

[270] *See* Frischmann, *Innovation and Institutions*, *supra* note 32, 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) ("Basic research is distinguished from applied research mainly by lacking *immediate* commercial applications.") (emphasis in original). I agree with Landes and Posner that the distinction between basic and applied depends upon the certainty with which particular applications are known. (I assume that by "immediate," Landes and Posner mean existing or expected to be available in the short term with a reasonable degree of certainty, which they later refer to as immediately foreseeable." *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 such situation may be troublesome from a social perspective precisely because it may stifle other follow-on areas of research.

[271] *See* previous note.

[272] *See, e.g.,* J. H. Reichman and Paul Uhlir, *A Contractually Reconstructed Research Commons for Scientific Data in a highly protectionist Intellectual Property Environment*, 66 LAW & CONTEMP. PROBS. 315 (2003); Rai, *Regulating Scientific Research*, *supra* note 209; LANDES & POSNER, ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW, *supra* note 267, at 305-08.

[273] R. Polk Wagner, *Information Wants To Be Free: Intellectual Property And The Mythologies Of Control*, 103 COLUM. L. REV. 995, 1001 (2003); William M. Landes & Richard A. Posner, *Indefinitely Renewable Copyright*, 70 U. CHI. L. REV. 471, 485; Carol Rose, *Romans, Roads, And Romantic Creators: Traditions Of Public Property In The Information Age*, 66 LAW & CONTEMP. PROBS 89, 90 (2003). Posner and Landes do point to an interesting demand-side congestion externality in the intellectual property context: "[T]rademark and right-of-publicity cases [are] both examples of intellectual property the value of which can be diminished by consumption." In a sense, these cases involve a situation that is akin to a network externality, except that it involves costs. Posner & Landes, *supra*, at 486.

[274] *See supra* Part II.B.

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.[275] Ultimately, the complicated economic puzzle involves balancing social benefits of access (*i.e.*, consumptive and productive use) versus 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 tradeoff reflected in the intellectual property literature and discussed in the previous section.[276]

When we focus on basic research, however, it is important to recognize that the balance tilts heavily toward access.[277] 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

[275] *See supra* Part II.A.

[276] *See supra* Part II.A. There are other tradeoffs 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) ("patent 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 (2004); Lemley, *Property, Intellectual Property, and Free Riding*, *supra* note 27, at 22-23. This tradeoff is a supply-side issue that derives first from the particular provisional mechanism (i.e., the market rather than government or some alternative) and second from a choice of institution (trade secret, patent). In the absence of intellectual property (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 (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.

[277] *See* TECHNOLOGICAL INFRASTRUCTURE POLICY: AN INTERNATIONAL PERSPECTIVE 8 n.3 (Teubal et al., eds. 1996) ("Conventional theory posits that widespread diffusion of knowledge generates static efficiency gains that are, to some degree, mitigates by losses in dynamic efficiency. The gains in static efficiency arise from wider application of innovations in the production of goods and services. But dynamic efficiency suffers to the extent that innovators perceive that they will be unable to fully exploit potential economic rents, thus undermining incentives to create new knowledge. However, this dichotomy fails to account for the positive dynamic implications attributable to the cumulative and integrative nature of the creation of science and technology knowledge. Thus, the widespread diffusion of this form of knowledge is likely to yield mutually reinforcing static and dynamic efficiency outcomes.").

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. It is well-recognized that granting exclusive property rights (*e.g.*, patents)[278] over basic research stifles (some) downstream research, which can impose substantial social costs.[279] This does not mean that no progress will be made. Some avenues of follow-on research may proceed, for example, by initial researchers or other to whom licenses are granted. The point is that basic research may "be encumbered with excessive licensing fees and transaction costs."[280]

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.[281] Thus, in making decisions regarding access, owners would face the same set of problems that our hypothetical owner of a lake might face (*e.g.*, transaction costs and uncertainty regarding the prospect of appropriable returns). While downstream uses are not rivalrous in the technical sense (*i.e.*,

[278] 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 OF INTELLECTUAL PROPERTY LAW, *supra* note 267, at 308, and that in some areas at least, both the existence and the prospect of patents has had significant effect on the research process.

[279] *See* LANDES & POSNER, ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW, *supra* note 267, at 305-07; Scotchmer, *Standing on the Shoulders of Giants*, *supra* note 89; Robert Merges & Robert Nelson, *On the Complex Economics of Patent Scope,* 90 COLUM. L. REV. 890 (1990). As Robert Merges explains, (some) private firms recognize the value of open access to basic research and have undertaken efforts to place research results in the public domain. Merges, *supra*.

[280] *See* Merges, *A New Dynamism in the Public Domain*, *supra* note 265, at 188.

[281] Not only does this bias affect management of existing research results, 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 209, at 109-13; *see also* Suzanne Scotchmer, *Standing on the Shoulders of Giants: Protecting Cumulative Innovators*, *in* INNOVATION AND INCENTIVES 139, 141 (forthcoming Jan. 2005) (on file with author) [hereinafter *Protecting Cumulative Innovators*] ("[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 171 ("One reason that basic research should be supported by public sponsors rather than private investors is that the benefits are hard to appropriate."). 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.

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 was a major premise behind the Bayh-Dole act and related legislation.[282]

This competitive dynamic may introduce rivalry in consumption and can drive owners to favor uses that can reasonably be expected to generate appropriable returns at the expense of uses more likely to generate positive externalities.[283] This may skew "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 dubbed "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.[284]

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

> [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. …
>
> 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,

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[282] *See infra* note 286-87 and accompanying text.

[283] *C.f.* Rai, *Proprietary Rights and Collective Action*, *supra* note 210, at 6 ("[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.").

[284] Frischmann, *Innovation and Institutions*, *supra* note 32, at 374; *id*. at 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.").

> restricted access to patented technologies has been identified as a significant barrier to development of subsistence crops relevant to the developing world. . . .[285]

More generally, the social costs associated with the market mechanism's inherent bias for outputs that generate observable and appropriable returns may be significant but evade observation because *basic research often is an input into (and output from) cumulative processes involving multiple inputs, multiple outputs, multiple actors, multiple research avenues heading in different directions, nonlinear progression, feedback loops, spillovers, and numerous other complications that frustrate modelers and defy simplification*.[286] All of these characteristics contribute to information and transaction cost problems that make relying on property-based, market-driven management of basic research results somewhat outrageous, much like the seemingly ridiculous hypothetical of granting ownership of Lake Michigan to an individual property owner.[287]

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 ought to take advantage of information's nonrival

[285] Rai, *Proprietary Rights and Collective Action*, *supra* note 210, at 8-9. 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.

[286] Consideration of these characteristics is beyond the scope of this article. There is a substantial literature. *See, e.g*., Scotchmer, *Protecting Cumulative Innovators*, *supra* note 278; Scotchmer, *Standing on the Shoulders of Giants*, *supra* note 89; Rai, *Regulating Scientific Research*, *supra* note 209, at 124; Frischmann, *Innovation and Institutions*, *supra* note 32;

[287] Edmund Kitch's "prospect theory" of patents simply does not work well for basic research. His theory is premised first on the notion that the property owner will minimize social waste associated with duplicative efforts and second on the notion 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). Both premises do not hold 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 variance in possible directions of research and outcomes, and, as discussed in the text, an exclusive focus on commercialization may result in significant social (opportunity) costs. *See* Frischmann, *Innovation and Institutions*, *supra* note 32, at 372-73, 374-76; *see also* Scotchmer, *Protecting Cumulative Innovators*, *supra* note 278, at 170 ("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, especially if second-generation products can cover their costs without it. 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.").

character and encourage widespread productive use downstream. But how do we overcome the production problem? Don't we need to strike a balance between access and control in order to encourage private investment?

There is a continuum of hybrid solutions (grants, procurement, subsidies, regulation, property rights, intellectual property rights, contract, tax incentives, technology, social norms, etc.) that respond implicitly to the fact that the 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 to rely on government funding. According to Landes and Posner, "[a]n 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 was financed by universities and other nonprofit research establishments out of their own funds."[288] This removes the need to rely on private investment and thus eliminates supply-side concerns over free-riding. Then, at least in theory, 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 upon the government to allocate limited public funds and to manage the research results efficiently. The capacity of the government to execute these functions efficiently has been subject to extensive criticism on institutional and public choice grounds. In fact, based in part on the perception that the government had a poor record of managing federally funded research results,[289] Congress enacted a series of legislative reforms, such as the Bayh-Dole Act.[290] These reforms generally were aimed at facilitating transfer of publicly funded technology to the private sector.[291] A major component of this

[288] LANDES & POSNER, ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW, *supra* note 267, at 306.

[289] *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) (explaining and critiquing this perception).

[290] *See* Bayh-Dole University and Small Business Patent Procedures Act, Pub. L. No. 96-517, 94 Stat. 3019 (Dec. 12, 1980) (codified at 35 U.S.C. §§ 200-211); *see also* Stevenson-Wydler Technology Innovation Act of 1980, Pub. L. 96- 480, 94 Stat. 2311-2320) (codified as amended at 15 U.S.C. § § 3701-3714 (1994)).

[291] On these legislative reforms, see Rebecca S. Eisenberg, *Public Research and Private Development: Patents and Technology Transfer in Government-Sponsored Research*, 82 VA L

reform effort involved permitting and encouraging federally funded researchers to obtain patent rights over their inventions. The basic rationale for this was that the government had failed to transfer (or instigate contractors to transfer) valuable technology to market actors who would have commercialized the results and that granting researchers patent rights would enable them to better manage the inventions.[292] In essence, relying 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 fundamental shift has already 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.[293] For basic research, coupling government funding with clear dedication to the public domain (and thus decoupling private intellectual property) remains a method for sustaining a commons that does not rely on either the government or the market mechanism to allocate access to the public.

For many other information resources that are infrastructure, the question of how to strike the appropriate balance between access and incentives is a matter reconciled primarily within the law of intellectual property.[294] While I leave a

REV 1663 (1996); Rebecca S. Eisenberg, *Technology Transfer and the Genome Project: Problems with Patenting Research Tools*, 5 RISK 163 (1994); Rai, *Regulating Scientific Research*, *supra* note 209, at 92-94, 109-15; Frischmann, *Innovation and Institutions*, *supra* note 32, at 406.

[292] *See* Eisenberg, *Public Research and Private Development*, *supra*.

[293] 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 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 id.* at 223-49 (suggesting that delays and high transaction costs stifle transfers of biotechnology research tools).

[294] 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. 109 S.Ct. 971 (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.119 S.Ct. 304 (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." Arti K. Rai & Rebecca S.

more complete discussion of intellectual property law issues pertaining to infrastructure for a separate paper, a brief discussion provides a flavor of how this balance is currently struck, and, at the same time, provides a point of contrast with the brief 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 in order to promote progress, advancement, and the continued expansion of the public domain over the long run as the exclusive rights expire.[295] More importantly, even before an intellectual property right expires, an important balance is struck even with respect to short term restriction on access—restricted access is limited in scope and open access is preserved for certain uses.[296]

First, the public gains access to the newly produced information in the sense that it is disclosed. Patents themselves serve as an important means of disclosing inventions to the public;[297] to be awarded a patent, the patentee must sufficiently describe the invention in the patent application to allow others to

Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 291 (2003).

[295] 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. 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 (copyright term is life of the author plus 70 years); 35 U.S.C. § 154(a) (patent term is 20 years from filing).

[296] *See, e.g.*, Jessica Litman, *The Public Domain*, 39 EMORY L.J. 965 (1990); LANDES & POSNER, ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW, *supra* note 267; *see also* Robert Heverly, *The Information Semicommons*, 18 BERKELEY TECH. L.J. 1127 (2003) (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 (restricted) and public (unrestricted) uses of information).

[297] 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* note 273. 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 (2001).

recreate the invention.[298] Competitors may be able to invent around the patent, essentially using the information as an input into their own productive activities.

Second, intellectual property law also imposes restrictions on the scope of coverage in a number of ways. 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 an algorithm or abstract idea. Subject matter limitations restrict patenting of extremely generic information. Moreover, patented inventions must be reduced to practice, novel, non-obvious, and useful. Copyrights generally cover artistic expression and not functional innovations. One cannot copyright ideas, only expression. To be copyrightable, material must feature an original expression fixated in a tangible media, such as books, film, or sound recordings.

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.[299] Fair use of a copyrighted work expressly encompasses purposes such as criticism, comment, news reporting, teaching, scholarship, and research,[300] and implicitly encompasses many other purposes that further the public interest.[301] Such uses may be excused from copyright infringement under the fair use doctrine.[302]

In the following sense, fair use is the inverse of the environmental regulation discussed earlier: Fair use preserves open access for certain productive uses[303] 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 these productive uses for which access is sustained involve the production of public and nonmarket goods that generate positive externalities realized by society as a whole. Fair use not only facilitates the creative process itself—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, but

[298] 35 U.S.C. § 112.
[299] 17 U.S.C. § 107.
[300] *Id.*
[301] *See, e.g.,* Sony Corp. v. Universal Studios, 464 U.S. 417 (1984) (interpreting the concept of fair use broadly because of the public interests at stake); Campbell v. Acuff-Rose Music, 510 U.S. 569 (1994) (acknowledging the strong public interest in critical works such as parody).
[302] 17 U.S.C. § 107.
[303] I am using the term "productive use" much more liberally than the dissent in *Sony*. Sony v. Universal City Studios, 464 U.S. 417 (1984).

the doctrine also facilitates experimentation and learning, processes that generate diffuse external benefits for society.[304]

There is some degree of sensitivity in both patent and copyright law for sustaining open access to information that is infrastructure, as exhibited by the idea-expression doctrine and the non-patentability of abstract idea.[305] 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.[306] In a separate article, I explore these issues and argue that institutions, such as intellectual property, ought to respond explicitly to the fact that the certain intellectual resources are infrastructure.

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

In the final part of this article, I demonstrate how the infrastructure theory applies to the Internet in the context of a particularly contentious "open access vs. private control" debate, specifically the ongoing debate over network neutrality. At the heart of this debate is whether the Internet will retain its end-to-end architecture and continue to be managed as a commons. 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

[304] *See* Julie Cohen, *The Perfect Curve*, *supra* note 41, at 1803-04 (explaining that the traditional economic analysis of the supply and demand curves for copyrighted information views the consumer surplus as benefits derived from consumption and not productive use); Lemley, *The Economics of Improvement in Intellectual Property Law*, *supra* note 97, at 1056-58; Lydia Loren, *Redefining the Market Failure Approach to Fair Use in an Era of Copyright Permission Systems*, 5 J. OF 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.").

[305] *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 (1980) ("The laws of nature, physical phenomena, and abstract ideas have been held not patentable.").

[306] 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 OF INTELLECTUAL PROPERTY LAW, *supra* note 267; LANDES & POSNER, THE POLITICAL ECONOMY OF INTELLECTUAL PROPERTY LAW, *supra* note 60.

commercial infrastructure optimized for the production and delivery of commercial outputs.[307] As Lessig reminds us in *The Future of Ideas*, there are "two futures in front of us."[308]

A. Internet as Infrastructure

The Internet consists of many infrastructure resources. Scholars have delineated two macro-level infrastructure resources—the *physical infrastructure*, which consists of a wide variety of physical networks interconnected with each other, and the *logical infrastructure*, which consists of the standards and protocols that facilitate seamless transmission of data across different types of physical networks.[309] The physical and logical infrastructure both act as essential inputs into downstream production of applications and content.[310] In contrast with the

[307] In Lessig's 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 60, at xiii-xiv. Lessig considers the processes by which culture is produced—open, free creative processes and controlled, permission-first processes—and argues that the law is changing to support the latter at the expense of the former. Although Lessig is focusing 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 outputs—commercial content.

[308] *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 7; Benkler, *From Consumers to Users*, *supra* note 13, at 568 (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 (2004) (same). Lessig, Benkler and Balkin vividly paint the picture of the Internet as a Commercial Infrastructure—an Internet *optimized* to deliver content-on-demand. LESSIG, *supra*, at 7; Benkler, *From Consumers to Users*, *supra* at 575-77; Balkin, *Digital Speech and Democratic Culture*, *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 affiliates) but also the "end-user's Internet experience" itself). Lessig paints a less vivid picture of the Internet as Commercial, Public and Social Infrastructure because, as he notes, it "is much harder to describe; . . . the very premise of the Internet is that no one can predict how it will develop." *Id.* Still, Lessig fills out this latter picture with detailed descriptions of the creative enterprises, technologies that enable users to engage more fully in the creative process, and how this enhances community and cultural values. *Id.*; *see also* LESSIG, FREE CULTURE, *supra* note 60 (providing a similar dichotomous picture of culture). Balkin has a similar vision as Lessig, although he is focused on the social value of promoting a democratic culture through the principle of free speech. *See* Balkin, *Digital Speech and Democratic Culture*, *supra*, at 3-4, 30-32; *see infra* text accompanying notes 369-72 (relating Balkin's free speech theory with infrastructure theory).

[309] *See, e.g.*, Benkler, *From Consumers to Users*, *supra* note 13.

[310] *See* Frischmann, *Internet Infrastructure*, *supra* note 36, at 34-41 (modeling the "extrinsic" nature 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

upstream-downstream/input-output model I have 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.[311] The number of layers in particular models varies, but the following four-layered model is sufficient for our purposes:

Layer	**Description**
Content	Information / data conveyed to end-users. *E.g.*, email communication, music, webpage.
Applications	Programs and functions used by end-users. *E.g.*, email program, media player, web browser.
Logical Infrastructure	Standards and protocols that facilitate transmission of data across physical networks. *E.g.*, TCP/IP, domain name system.
Physical Infrastructure	Physical hardware that comprise interconnected networks. *E.g.*, telecommunications, cable and satellite networks; routers and servers; backbone networks.

As the structure of this layered 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 wll 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.[312]

distributing such content (*e.g.*, peer-to-peer software, email, instant messaging, chat rooms, the World Wide Web, etc.). Further, as discussed below, there is a considerable amount of content for which the Internet is an "essential" input to production (*e.g.*, blogs, webpages, peer/consumer annotated books). On the last example, see http://free-culture.cc/remixes/.

[311] *See, e.g.*, Farrell & Weiser, *Modularity, Vertical Integration, and Open Access Policies*, *supra* note 6, at 90-91; 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. (forthcoming Fall 2004); Kevin Werbach, *A Layered Model for Internet Privacy*, 1 J. ON TELECOMM. & HIGH TECH. L. 37, 57-64 (2002); Benkler, *From Consumers to Users*, *supra* note 13; Douglas C. Sicker & Joshua L. Mindel, *Refinements of a Layered Model for Telecommunications Policy*, 1 J. ON TELECOMM. & HIGH TECH. L 69 (2002).

[312] Many of these downstream outputs also may constitute infrastructure (*e.g.*, a web browser). I will not focus on them in this article, however.

All three demand-side criteria for infrastructure are met. The Internet infrastructure is a potentially nonrival good; it is sometimes consumed nonrivalrously and sometimes consumed rivalrously, depending upon available capacity.[313] 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. Thus, end-users create demand for Internet infrastructure by virtue of their demand for applications and content.

The Internet currently is all three types of infrastructure—commercial, public and social infrastructure. As described below, the Internet is perhaps the clearest example of an infrastructure resource that enables the production of a wide variety of public, private, and non-market goods, many of which are network goods.[314]

Like most traditional infrastructure, the Internet currently is managed as a commons.[315] The Internet infrastructure seen today has evolved with the "end-to-end" design principle as a central tenet.[316] 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).[317] End-to-end essentially means that infrastructure providers cannot differentiate (or discriminate) among data packets carried by their networks.[318] This design principle promotes the open interconnection of networks and focuses application development and innovation on the demands of end-users.[319] For the most part,

313 *See* Frischmann, *Internet Infrastructure*, *supra* note 36, at 24-34 (modeling the "intrinsic" nature of the Internet infrastructure). To be more precise, the physical infrastructure and certain components of the logical infrastructure such as domain name space are potentially (non)rival in the sense 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.

314 *See supra* Part II.C.

315 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").

316 LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 34-35; Frischmann, *Internet Infrastructure*, *supra* note 36.

317 *See* Farrell & Weiser, *Modularity, Vertical Integration, and Open Access Policies*, *supra* note 6, at 91 (describing how the Internet Protocol implements the end-to-end architecture).

318 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).

319 *Id.*

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.[320] In a sense, this shared ignorance, "built" into the infrastructure, precludes exclusion of end-users or end-uses on an individualized basis.[321]

The institution that sustains the Internet infrastructure commons is a social norm (embodied in the widespread adoption of technical standards), and it is subject to change.[322] 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, including the Internet's evolution to broadband (infrastructure, applications, and content), the rapid 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.[323] We should resist this pressure and more carefully think through the benefits of sustaining an Internet infrastructure commons.

B. The Network Neutrality Debate and the Future of End-to-End

For the past two decade, academics, commercial entities, technologists, government officials, universities, and citizens have debated about the future of the Internet Infrastructure.[324] In the mid-1980s, participants in such debates focused on technology issues and coordinating interconnection among different types of networks.[325] In the late-1980s and early-1990s, attention shifted (by no

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[320] Frischmann, *Internet Infrastructure*, *supra* note 36, at 27.

[321] *Id*.

[322] Lemley & Lessig, *The End of End-to-End*, *supra* note 315.

[323] *See* Bruce M. Owen & Gregory L. Rosston, *Local Broadband Access: Primum Non Nocere or Primum Processi? A Property Rights Approach*, Stanford Law School Working Paper 263 (2003) (suggesting that the end-to-end architecture has stifled investment in broadband infrastructure and applications and thus slowed broadband deployment); *see also* Frischmann, *Internet Infrastructure*, *supra* note 36, at 8-9, 12-13, 15, 18 (explaining how the "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.").

[324] These debates are extensively covered elsewhere and will not be recounted here. *See generally See* JANET ABBATE, INVENTING THE INTERNET (1999).

[325] *See id*.; Frischmann, *Internet Infrastructure*, *supra* note 36, at 12-15.

means entirely) to the viability of privatization and commercialization.[326] Since the privatization and commercialization process was more or less complete in 1995, attention has shifted to governance and (de)regulation.[327]

Considerable attention has been given to the question of what degree of control infrastructure providers (network owners) should have over their privately-owned networks[328]—essentially, an "open access vs. control" debate that involves the same set of economic issues discussed in previous parts with respect to traditional infrastructure and environmental and information resources that behave like infrastructure. A substantial literature approaches the question from a variety of perspectives, including law,[329] economics,[330] and technology.[331] The current debate is skewed, however, because it focuses myopically on neutrality, market-driven provision of commercial outputs, and innovation. A

[326] ABBATE, *supra* note 321; BRIAN KAHIN, COMMERCIALIZATION OF THE INTERNET: SUMMARY REPORT, RFC 1192 (Nov. 1990); 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. UNIV. L.Q. 89 (2001); Frischmann, *Internet Infrastructure*, *supra* note 36, 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.").

[327] *See, e.g.*, Tim Wu, *The Broadband Debate: A User's Guide*, J. TELECOMM. & HIGH TECH. L. (forthcoming 2004) (manuscript at 6-9), available at http://ssrn.com/abstract=557330); Michael Powell, *Preserving Internet Freedoms: Guiding Principles for the Industry*, at 4 (February 8, 2004), at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-243556A1.pdf.

[328] For example, in the context of emerging broadband infrastructure, the term "open access" 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, *Modularity, Vertical Integration, and Open Access Policies*, *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 and Broadband Discrimination*, 2 J. TELECOM. & HIGH TECH 141 (2003).

[329] *See, e.g.*, Glenn A. Woroch, *Open Access Rules And The Broadband Race*, 2002 L. Rev. Mich. St. U. Det. C.L. 719; Lemley & Lessig, *The End of End-to-End*, *supra* note 315; Phil Weiser, P*aradigm Changes in Telecommunications Regulation*, 71 COLO. L. REV. 819 (2001); 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, 77-90 (2000).

[330] *See, e.g.*, Bruce M. Owen & Gregory L. Rosston, *Local Broadband Access: Primum Non Nocere or Primum Processi? A Property Rights Approach*, Stanford Law School Working Paper 263 (July 2003); Paul David, *The Beginnings and Prospective Ending of 'End-to-End': An Evolutionary Perspective of on the Internet's Architecture*, 17 OXFORD REVIEW OF ECONOMIC POLICY 17 (2001). In many respects, the approach taken in this Part follows David's lead.

[331] Marjory S. Blumenthal & David D. Clark, *Rethinking the design of the Internet: The end to end arguments vs. the brave new world*, *at* http://ana.lcs.mit.edu/papers/PDF/Rethinking_2001.pdf.

new approach in needed because there is much more at stake than the current debate reflects.

1. Network "neutrality"

In two recent articles, Professor Tim Wu summarizes the current status of the ongoing "open access vs. control" debate and couches the debate as being about "network neutrality"—that is, whether and if so how the Internet should be made to be *neutral*.[332] Together with Lawrence Lessig, Wu also submitted an ex parte letter to the Federal Communications Commission (FCC) explaining their view that network neutrality ought to be an "aspiration" for the FCC.[333] In his two papers, Wu provides a fair assessment of the current debate. Accordingly, I 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 different policy issues, I will focus exclusively on the future of the end-to-end architecture of the Internet. So how does the end-to-end design principle relate to network neutrality?

One might think that implementing a commons via end-to-end network design is "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) is "non-neutral." The problem with this view is that neutrality is a "finicky" concept.[334] As Wu explains:

> 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.

[332] *See* Wu, *Network Neutrality and Broadband Discrimination*, *supra* note 325; Wu, *The Broadband Debate*, *supra* note 324.
[333] Letter from Timothy Wu, Assoc. Prof., Univ. of Virginia Law School, and Lawrence Lessig, Prof., Stanford Law School, to Marlene H. Dortch, Secretary, FCC, CS Docket No. 02-52, at 3 n.3 (Aug. 22, 2003) [hereinafter "Letter from Wu and Lessig to FCC"].
[334] Wu, *Network Neutrality and Broadband Discrimination*, *supra* note 325, at 7.

> . . . 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.[335]

Wu (and others) are correct in saying that the end-to-end design precludes differentiated QoS,[336] and thus disfavors latency-sensitive applications, such as IP telephony and video-on-demand.[337] To be sure, this may be one significant cost of sustaining an infrastructure commons.[338] Furthermore, proponents of an "intelligent" Internet argue that the end-to-end design of the Internet inhibits other socially valuable applications that would best be executed at the "core" rather than the "ends"—for example, security and spam regulation measures.[339] While the relative effectiveness and costliness of executing various functions at the "core" or the "ends" is a subject of debate, this also may be one significant cost of sustaining an infrastructure commons.

But the fact that end-to-end design favors one set of applications does not mean that shifting to QoS will not as well. 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 commercial applications that generate observable and appropriable returns. While the bias would not be technologically determined (as in the case of end-to-end design), it would be determined by the predictable operation of the market mechanism. As

[335] *Id.* at 6-7 (footnotes omitted).

[336] The Internet currently provides best effort data delivery, which is a simple form of QoS. *See id.* at 7-8. 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.

[337] *See* Wu, *Network Neutrality and Broadband Discrimination*, *supra* note 325; Yoo, *Would Mandating Broadband Network Neutrality Help or Hurt Competition?*, *supra* note 308.

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

[339] *See* Blumenthal & Clark, *Rethinking the design of the Internet*, *supra* note 328; Yoo, *Would Mandating Broadband Network Neutrality Help or Hurt Competition?*, *supra* note 308; David, *The Beginnings and Prospective Ending of 'End-to-End'*, *supra* note 327.

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).[340]

End-to-end design sustains a commons by insulating end-users from market-driven control over access.[341] Because infrastructure 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, competition in upstream and downstream markets,[342] and competition in innovation markets.[343] For example, Lawrence Lessig, a major proponent of sustaining end-to-end, focuses extensively on the notion of sustaining an *innovation commons* and the idea that experimentation, tinkering, and uninhibited creation of new applications and content—*innovation*—are critical productive

[340] *See supra* Parts II.B-D, III.A (explaining inherent bias of the market for observable and appropriable returns). Note that I am leaving aside concerns over anticompetitive behavior.

[341] *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 46. For discussion of this point more generally, see supra Part II.D.

[342] *See, e.g.*, Farrell & Weiser, *Modularity, Vertical Integration, and Open Access Policies*, *supra* note 6 (focusing on sustaining competition in upstream and downstream markets); Bruce M. Owen & Gregory L. Rosston, *Local Broadband Access: Primum Non Nocere or Primum Processi? A Property Rights Approach*, Stanford Law School Working Paper 263 (July 2003) (focusing on commercial markets and arguing that a property rights approach is preferable to common carrier-type regulation); Yoo, *Would Mandating Broadband Network Neutrality Help or Hurt Competition?*, *supra* note 308 (framing the network neutrality debate in competition theory); *c.f.* Karl Manheim & Lawrence B. Solum, *An Economic Analysis of Domain Name Policy*, Research Paper No. 2004-7 (Mar. 2004) (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).

[343] *See* Wu, *Network Neutrality and Broadband Discrimination*, *supra* note 325; Wu, *The Broadband Debate*, *supra* note 324; Letter from Wu and Lessig to FCC, *supra* note 330, at 3-6.

activities facilitated by the end-to-end architecture of the Internet.[344] Lessig is correct, but he could and should go much further.

While necessarily an integral part of the debate, innovation ought not be the linchpin upon which end-to-end architecture of the Internet hangs.[345] Innovation is too narrow conceptually because of its traditional economic connection with the competitive process and commercial markets.[346] As discussed in the next section, there is a substantially wider range of socially valuable downstream activities that are not really innovative or commercial.[347]

[344] *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7.

[345] 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. *C.f.* Wu, *The Broadband Debate*, *supra* note 324 ("[T]he greatest unifying belief as between openists and deregulationists 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 email, chat rooms, and message boards, for example.

[346] 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." *Id.* at 6; *see also id.* at 10 ("Though most distinguish innovation from creativity, or creativity from commerce, I do not"); 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 32, at 348-49 (criticizing the link to commercialization and adopting a broader definition). Lessig emphasizes in THE FUTURE OF IDEAS that he is concerned with innovation *and* creativity. While I fear that participants in the network neutrality debate tend to focus on innovation, I should note that creativity also is too narrow a concept because it does not fully capture the range of socially valuable productive activity made possible by the Internet. *See infra* next section; *see also* Frischmann, *Internet Infrastructure*, *supra* note 36, at 68-69 ("As a recent article in the *Economist* observed, '[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.") (quoting *Upgrading the Internet*, THE ECONOMIST (TECH.Q.), Mar. 24, 2001, at 32).

[347] Lessig knows this and clearly intends to use innovation broadly. *See supra* note 343.

The consequence of focusing on innovation is that the debate has been framed in terms of competition theory.[348] For example, Wu argues that network neutrality ought to be accepted both by "openists" and "deregulationists" as the operative normative goal based on the Schumpeterian view of innovation as an essential part of an evolutionary competitive process.[349] (Wu and Lessig make the same argument in their letter to the FCC.)[350] From the Schumpeterian perspective, innovation is about the creation and distribution of new commercial outputs (products and processes) that will drive competition with incumbents, a process Schumpeter famously referred to as "creative destruction."[351] Wu suggests that a neutral Internet will support "meritocratic" competition among all applications (new and old),[352] "a Darwinian competition among every conceivable use of the Internet so that only the best survive."[353] This view leaves unanswered important questions: By what process will such competition take place? On what metric do we assess what constitutes the "best"?[354] Presumably, he, like Schumpeter, expects that competitive markets will effectively "judge" the merits of innovative applications on the basis of consumer demand (consumers' willingness to pay). The problem with this perspective is that market competition

[348] For a thorough competition-oriented analysis, see Farrell & Weiser, *Modularity, Vertical Integration, and Open Access Policies*, *supra* note 6; *see also* Philip J. Weiser, *Toward A Next Generation Regulatory Regime*, 35 LOY. U. CHI. L. REV. 41, 74-84 (2003) (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*, at 96. Their central analytical tool is the economic concept of "internalizing complementary externalities" ("ICE"), which suggests that firms will manage their resources openly when doing so "enhances consumer value." *Id*. They explore this concept and eight important limitations. *Id.* at 105-19. Farrell and Weiser do not, however, explore the demand-side problems highlighted in this article.

[349] In his first article, Tim Wu makes an abbreviated and admittedly simple case for network neutrality based on the Schumpeterian view of innovation as 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 and Broadband Discrimination*, *supra* note 325, at 4-6, 7. 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 324, at 6-9.

[350] *See* Letter from Wu and Lessig to FCC, *supra* note 330, at 5-8 (arguing that network neutrality is critical to sustaining an "evolutionary, or competitive model of innovation").

[351] J.A. SCHUMPETER, CAPITALISM, SOCIALISM AND DEMOCRACY, 5th ed. 1976.

[352] *See* Wu, *The Broadband Debate*, *supra* note 324; Wu, *Network Neutrality and Broadband Discrimination*, *supra* note 325, at 5.

[353] Wu, *Network Neutrality and Broadband Discrimination*, *supra* note 325.

[354] Will uses compete in a market setting 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? And so on.

"judges" the merit of outputs on the basis of observable and appropriable returns rather than overall social welfare.[355]

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 innovation.[356] The Schumpeterian evolutionary perspective does yield important insights that are relevant to the analysis of infrastructure resources. For example, as noted earlier with respect to a lakes and basic research,[357] and as Wu describes:

> Several policy prescriptions come from the consensus neo-Schumpeterian analysis []. The insight that all should agree on is that maintaining lowest-cost market entry as possible is the foundation of the innovation theories that all 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. But all should understand that the process will be an ugly, Darwinian affair, an interminable exercise in trial and error, and not the well-calculated elegance of monopolistic prophecy.[358]

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 very important, relevant to the debate, and deserving of careful attention. Furthermore, I agree with Wu, Lessig and others as a general matter regarding the significant benefits that a theoretically neutral system has for innovation from an evolutionary perspective. However, I do not think that true neutrality is attainable, nor do I believe the Internet is a system focused on facilitating innovation alone.

3. Internet as Commercial, Public and Social Infrastructure

[355] *See supra* Part II and III.
[356] *See* Wu, *The Broadband Debate*, *supra* note 324, at 9-12.
[357] *See supra* Part III.
[358] Wu, *The Broadband Debate*, *supra* note 324, at 9.

The Internet is a mixed commercial, public and social infrastructure.[359] Yet the public and social infrastructure aspects of the Internet 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.[360]

Consider what makes the Internet valuable to *society*.[361] What is the social value of the Internet? 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 non-market goods. Despite such difficulty, we know that the Internet is "transforming our society."[362] The transformation is similar to transformations that we have experienced in the past with other infrastructure,[363] yet things are changing in a more rapid, widespread and dramatic fashion.[364]

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[359] 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 consumption by an end-user 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). But these processes are likely to be strictly tailored to channeling end-users to purchasing and consuming commercial content. *See* Jack Balkin, *Digital Speech and Democratic Culture: A Theory of Freedom of Expression for the Information Society*, 79 N.Y.U. L. REV. 1, 14 (2004).

[360] *See supra* Part II.D.

[361] 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 email and instant messaging, the World Wide Web, and file sharing.

[362] PRESIDENT'S INFO. TECH. ADVISORY COMM., INFORMATION TECHNOLOGY RESEARCH: INVESTING IN OUR FUTURE 11, 11-20 (Feb. 1999), available at http://www.ccic.gov/ac/report/pitac_report.pdf.

[363] *Id*. at 11.

[364] *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

The Internet environment 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 are being transformed by the Internet. And 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 observes, the "digital revolution makes possible widespread cultural participation and interaction that previously could not have existed on the same scale."[365]

The Internet opens the door *widely* for users, and most importantly, it opens the door to many different activities that are productive. End-users actively engage in innovation and creation;[366] speak about anything and everything;[367] maintain family connections and friendships; debate, comment, and engage in political and non-political discourse; meet new people; search, research, learn, and educate; and build and sustain communities.[368]

These are the types of productive activities that generate substantial social value, value that evades observation or consideration within conventional economic transactions.[369] When engaged in these activities, end-users are not

("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.").

[365] Balkin, *Digital Speech and Democratic Culture*, *supra* note 356, at 2. In this article, Jack 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. As discussed below, I believe his arguments for free speech parallel my own economic arguments for managing public and social infrastructure as commons, at least in the context of the Internet.

[366] *See* LESSIG, THE FUTURE OF IDEAS, *supra* note 7; Balkin, *Digital Speech and Democratic Culture*, *supra* note 356, at 31-32.

[367] "[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." Balkin, *Digital Speech and Democratic Culture*, *supra* note 356, at 31.

[368] *Id.* at 32.

[369] *See* ROBERT E. LITAN & ALICE M. RIVLIN, BEYOND THE DOT.COMS: THE ECONOMIC PROMISE OF THE INTERNET 5 (2001) (noting that "Not all of the economic benefits of the Internet will show up in productivity statistics" and suggesting that "these hard-to-quantify benefits . . . are

passively consuming content delivered to them, nor are they producing content solely for controlled distribution on a pay-to-consume basis.[370] Instead, they are interacting with each other and building, developing, producing and distributing public and non-market goods.[371] As a result of public participation in such activities, there are external benefits that accrue to society as a whole (online and offline) that are not captured or necessarily even appreciated by the participants.

Consider the fact that a significant portion of the data traveling on the Internet is noncommercial, speech-oriented information—whether personal emails and webpages, blog postings, instant messaging, government documentation, etc.[372]—and the economic fact that such information is a pure public good generally available for both consumption and productive use by 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.[373] 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. However, diffusion of small-scale positive

important even if they never enter the measured output of the economy"); *see also id.* at 45-63 (discussing some "benefits of the Internet that may not show up in the GDP").

[370] 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.

[371] "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 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, *Digital Speech and Democratic Culture*, *supra* note 356, at 32.

[372] Consider, for example, the recent findings of the Pew Internet & American Life Project regarding content creation and distribution online. A significant percentage of Internet users produce and distribute content and interact online (44%). The types of productive activities range from posting content such as photographs to interactive products such as blogs. *See* AMANDA LENHART ET AL., PEW INTERNET & AMERICAN LIFE PROJECT, CONTENT CREATION ONLINE (Feb. 2004).

[373] Active participation in these activities by some portion of society benefits even that portion of society that does 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 the Internet; the social benefits spillover. For example, when bloggers engage in a heated discussion about the merits of proposed legislation or the Iraq war, citizens that never use the Internet benefit because others have deliberated.

externalities still can lead to a significant social surplus when the externality-producing activity is widespread. This seems to reflect in economic terms the basic idea underlying Balkin's democratic culture theory.[374]

Widespread, interactive participation in the creation, molding, distribution, and preservation of culture,[375] 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. Balkin focuses on a theory of free speech as the means for pursuing this ideal. I focus on a complementary theory of an infrastructure commons as the means for pursuing the same ideal.

4. *Reframing the 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*.

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*.[376] What type of infrastructure do we as a society desire? Do we prefer an Internet infrastructure managed as a commons? 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.[377]

> [Note to reviewers: Compare Network neutrality balancing charts from appendix: *A simplified view of the current debate* and *modified by infrastructure theory*]

[374] Balkin, *Digital Speech and Democratic Culture*, *supra* note 356. *See also* Neil Netanel, *Copyright and a Democratic Civil Society*, 106 YALE L.J. 283 (1996) (similar theory although focused on copyright law as the relevant infrastructure)/

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

[376] *C.f.* 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*").

[377] *See* David, *The Beginnings and Prospective Ending of 'End-to-End'*, *supra* note 327.

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 in order 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 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 as a commons avoids government and market failure but, as with many traditional infrastructure, leaves some issues to be resolved.

In the context of the Internet, the viability of open access may depend (politically) upon whether there are alternative means for addressing 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 content. Another possible solution is to regulate consumptive content from the ends, for example, by taxing or regulating spam.[378] 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 R&D 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.

In the end, applying the infrastructure theory to this optimization problem does not solve the problem or provide a definitive 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, the infrastructure theory provides a better

[378] This is actually a lesson to be learned from the 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.

theoretical framework for understanding and evaluating "the *character of the* [*Internet*] and how it *relates to* [us as] *a community.*"[379]

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 that constitute the Environment but also the 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, manage and construct it as best we can. Unfortunately, we under-appreciate—often taking for granted as a given—the fundamental infrastructure resources upon which these systems depend.

The ubiquitous open access (commons) vs. private control debate is really a battle over *our environment*, how it is constituted, how it is experienced, and how it will evolve. The debate is raging and the subject of increasing economic, political and social conflict. Yet we barely understand the wide variety of interests at stake in this conflict, and we barely pause to seek a better understanding.

This article devotes much needed attention to developing a better understanding of 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 which means 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 is suggestive in the sense that it implies a connection and the need to carefully evaluate the merits in context and with an awareness of the wide variety of interests at stake. The infrastructure typology developed in the article distinguishes between *commercial, public and social infrastructures* based on the manner in which value is created for and realized by society; this provides a useful framework for evaluating the case for commons management.

In a sense, the infrastructure theory itself constitutes an infrastructure that can facilitate cross-disciplinary analysis of fundamental resources in a more

[379] LESSIG, THE FUTURE OF IDEAS, *supra* note 7, at 21.

comprehensive fashion. The infrastructure theory is applicable in a wide number of resource-focused disciplines and should serve as a platform for further research. Here are a few of many 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 of further demand-side analysis, including, for example, roads, communications networks, and legal systems; lakes, the atmosphere, and ecosystems; basic research, operating systems, and generic technology; the 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 this role is critical to improving decision-making regarding resource management.

Comparative analysis of the legal and social institutions. Property rights, regulation, social norms, and other institutions sustain infrastructure resources as commons. 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.

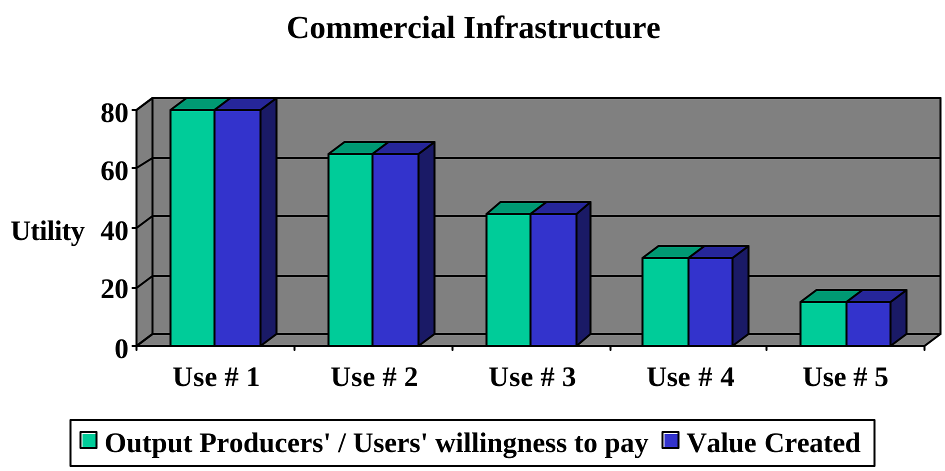
Analysis of the interplay of infrastructure theory with antitrust law. Under certain market conditions, antitrust principles, such as the essential facilities doctrine, may require an input supplier to make the input openly accessible to output producers. Such principles generally involve an incomplete and under-theorized version of infrastructure theory. Interestingly, the doctrine has been adopted in the European Union and elsewhere outside the United States at a time when the U.S. Supreme Court severely questioned its wisdom in a recent decision.[380]

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, substantial changes have taken place in developing and developed countries with

[380] *See* Verizon Communications Inc. v. Law Offices of Curtis v. Trinko LLP, 540 U.S. __ (2004) (Case No. 02-682).

respect to the manner in which infrastructure is provided to society. In the developing world, development 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 needed lens for distinguishing between commercial, public and social infrastructure and for evaluating such reform efforts.

APPENDIX: CHARTS AND DESCRIPTIONS



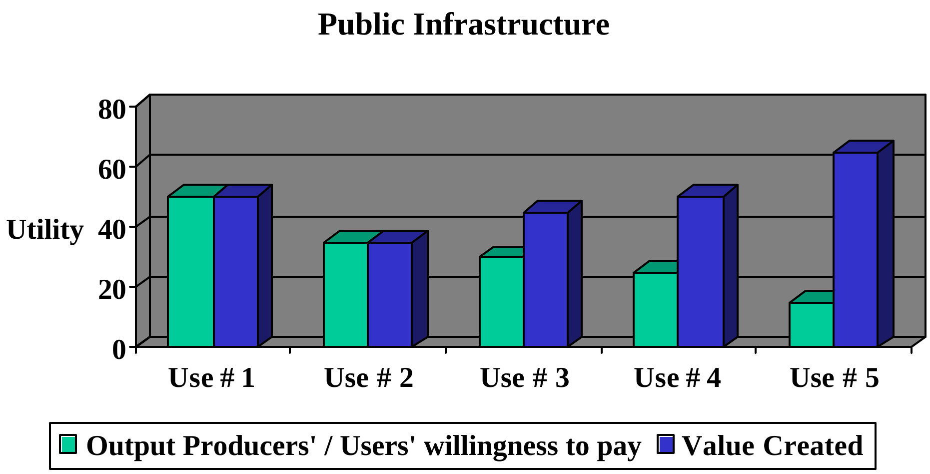
Definition: **Nonrival (or potentially nonrival) input into the production of a wide variance of private goods.**

Notes:

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.

Examples:

1. Railway transport
2. Telecommunication networks
3. Cable television
4. Internet



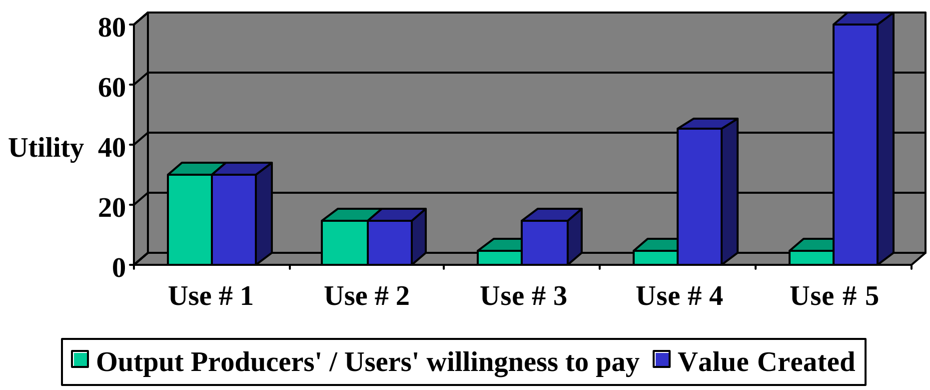
Definition: **Nonrival (or potentially nonrival) input into the production of a wide variance of public goods.**

Notes: *See also* the chart for *Basic Research as Infrastructure*.

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 (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.

Examples:
1. Basic research
2. Governance systems
3. Ideas
4. Internet

Social Infrastructure



Definition: **Nonrival (or potentially nonrival) input into the production of a wide variance of nonmarket goods.**

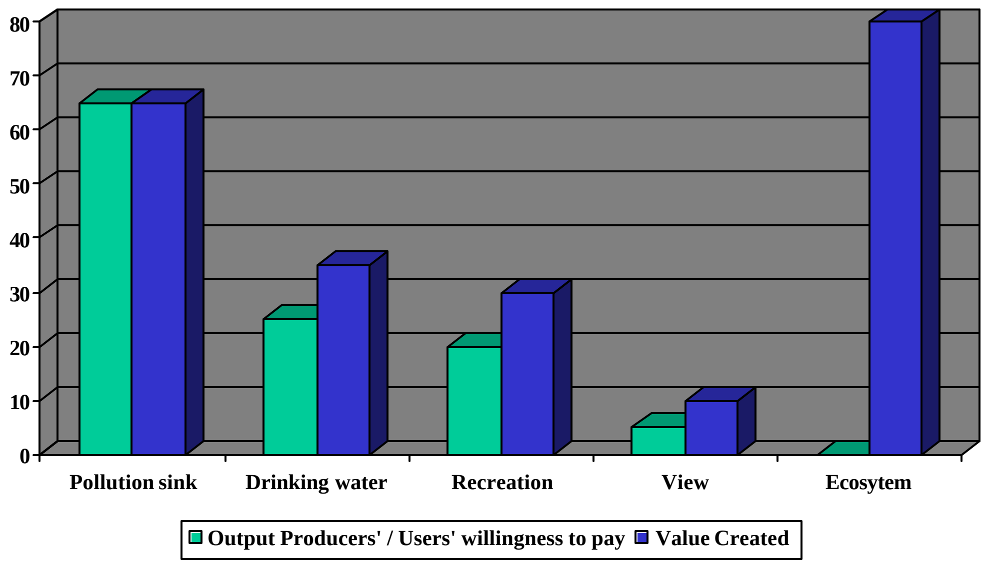
Notes: *See also* the chart for *Lake as Infrastructure*.

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.

Examples:

1. Ideas
2. Lakes
3. Governance systems
4. Internet

LAKE AS INFRASTRUCTURE

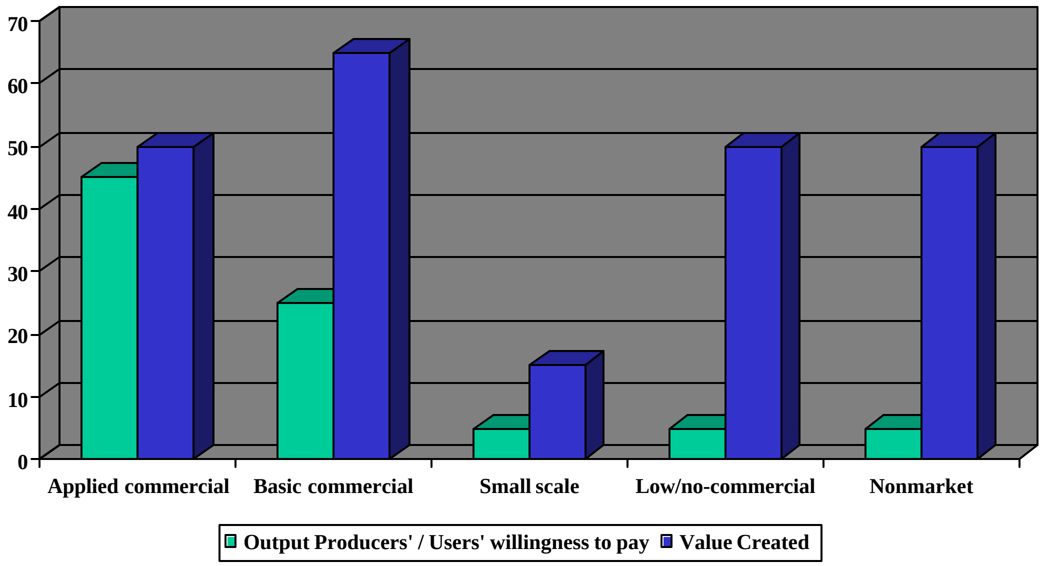


Notes:

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.

BASIC RESEARCH AS INFRASTRUCTURE



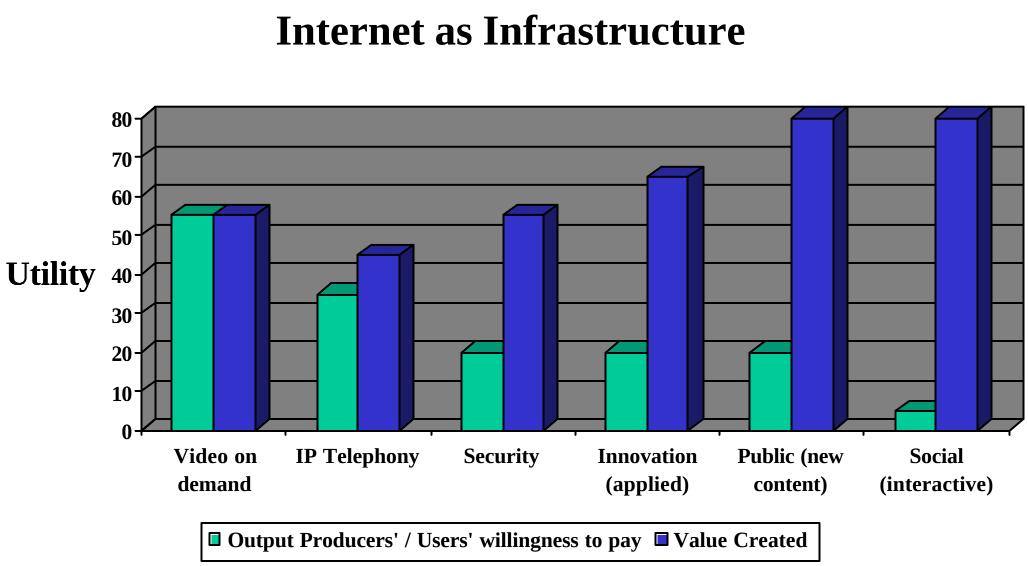
Notes:

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).[381] 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.

[381] Rai, *Proprietary Rights and Collective Action*, *supra* note 210; Kevin Outterson, *Pharmaceutical Arbitrage: Balancing Access and Innovation in International Prescription Drug Markets*, YALE JOURNAL OF HEALTH POLICY, LAW, AND ETHICS (2004).

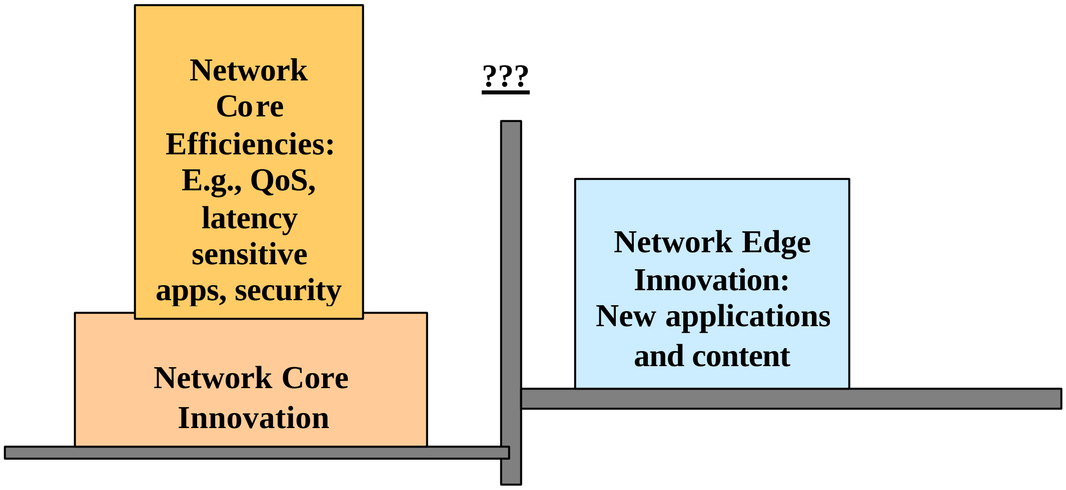
INTERNET AS INFRASTRUCTURE

The following chart is based entirely on qualitative values that are not meant to reflect market valuations of any of the listed sets of applications or content types. The chart does not distinguish between the physical and the logical infrastructure of the Internet; nor does it draw a clear distinction between applications and content.



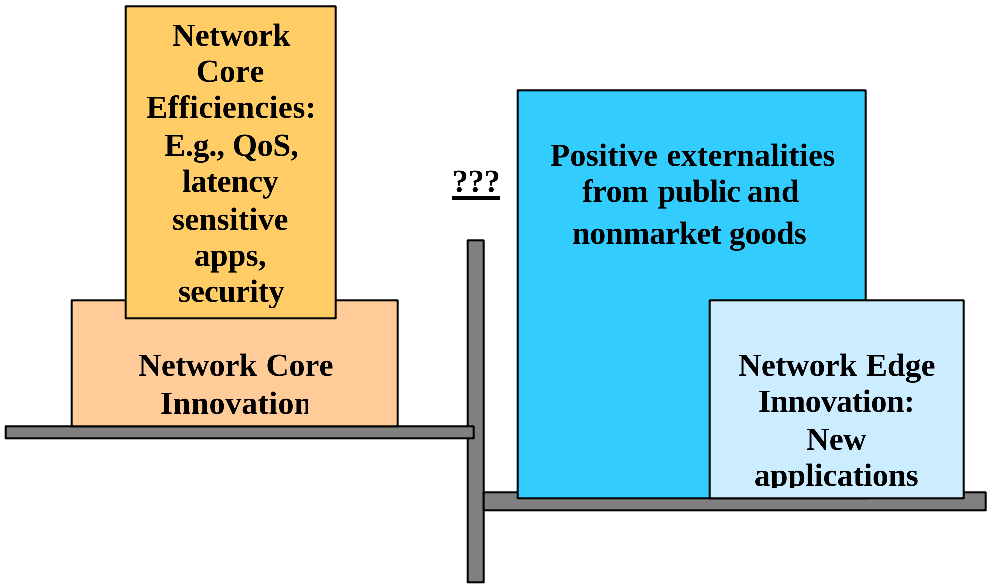
Notes:

Uses are ranked based on users' willingness to pay. Uses 1, 2, and 3 are frequently used examples of services and applications that support a migration from a "dumb" infrastructure that does not discriminate among end-users or end-uses to an "intelligent" network capable of offering differentiated quality of service for different end-users or end-uses. Uses 1 and 2 are time sensitive and require prioritization during periods of congestion. Video on demand is an application that will deliver content to end-users for direct consumption, a service for which consumers are ready and willing to pay. IP telephony is an application that will enable direct telephonic communications between end-users and may generate some external benefits. Use 3 (security) calls for an intelligent discriminating network for somewhat different reasons tan Uses 1 and 2. Basically, governments and corporations would like to be able to keep track of those packets that pose security risks to facilitate, for example, the functional equivalent of wire tapping online and security features for e-commerce transactions. Security is generally recognized as a public good which output producers and consumers undervalue. In contrast with the first three relatively specific applications, Uses 4, 5, and 6 are broad categories (hence the need to ignore the actual numbers used in the chart except for purposes of illustration).



Network *Neutrality* Balancing:

An oversimplified view of the current debate



Network *Neutrality* Balancing:

Modified by Infrastructure Theory