FROM WIFI TO WIKIS AND OPEN SOURCE: THE POLITICAL ECONOMY OF COLLABORATIVE PRODUCTION IN THE DIGITAL INFORMATION AGE

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INTRODUCTION

In August 2005, *Wired* magazine's cover story stated that collaborative production is the near future's "main event."[1] *Wired*, marking the 10th anniversary of the initial public offering of Netscape, also declared that a revolution was occurring that penetrates to the core of daily life with the transformation of consumers into producers.[2] Among the evidence of this transformation is hyperlinking, which creates the electricity for "ordinary folks to invest huge hunks of energy and time into making free encyclopedias, creating public tutorials for changing a flat tire, or cataloging the votes in the Senate."[3] *Business Week* confirmed this transformation when it ran a similar story a month later with the headline, "It's A Whole New Web."[4]

In the presence of digital computer/communications platforms, the dramatic growth of collaborative activities constitutes the emergence of a new mode of information production based on the superior economics of collaborative production. This new mode of production challenges fundamental concepts of the role and function of property and commercial relationships in the production of information goods. However, to develop definitions of and describe the success of collaborative production, the definition of public goods and common pool resources must be extended.[5] This is because although public goods and common pool resources exhibit traits of non-rivalry and non-excludability, collaborative goods exhibit characteristics of anti-rivalry and inclusiveness.[6] In addition, concepts such as commons and non-commodified relations must be included to understand fully the dynamics of collaborative production.

The dramatic success of collaborative networks poses a challenge, not only to the dominant economic paradigm, but also to a broad range of received social science thinking.[7] Traditional economic analysis hypothesized that large producers would reap the benefits of network externalities by tracking usage and targeting users with a form of cyberspace direct mail on steroids combined with instant point and click gratification that would deliver sales of large, bundled packages.[8] Sociologists feared an acceleration of

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[1] K. Kelly, *10 Years That Changed the World*, WIRED, August 2005, at 132.
[2] *See* Yochai Benkler, *From Consumers to Users: Shifting the Deeper Structure of Regulation Toward Sustainable Commons and User Access*, 52 FED. COMM. L.J. 561, 562 (2000) (providing an early, scholarly discussion of the transformation of consumers into producers).
[3] Kelly, *supra* note 1.
[4] Robert D. Hof, *It's a Whole New Web*, BUSINESS WEEK, Sept. 26, 2005, at 79.
[5] The most prominent example of open source software, Linux, "ought to be at the worse end of the spectrum of public goods because it is subject additionally to "collective provision." STEVEN WEBER, THE SUCCESS OF OPEN SOURCE 5 (2004).
[6] *Id*. at 154 (introducing the concept of antirivalness).
[7] Peter Levine, *The Internet and Civil Society: Dangers and Opportunities*, INFORMATION IMPACTS MAGAZINE, May 2001 (expressing concern over the decline of face-to-face relations); Peter Levine, *Can the Internet Rescue Democracy? Toward an ON-Line Commons*, *in* DEMOCRACY'S MOMENT REFORMING THE AMERICAN POLITICAL SYSTEM FOR THE 21ST CENTURY (Ronald Hayuk and Kevin Mattson eds., (2002); S. COLEMAN & J. GOTZE, BOWLING TOGETHER: ONLINE PUBLIC ENGAGEMENT IN POLICY DELIBERATION (2002) (regarding social relations).
[8] Y. Bakos & E. Brynjolfsson, *Bundling and Competition on the Internet: Aggregation Strategies for Information Goods*, 19 MKTG. SCI. 63, (2002).

isolation in the *Bowling Alone* syndrome,[9] as the focal point of interaction shifted from the face-to-face physical world to the anonymous, fleeting interactions in cyberspace.[10] Political scientists, applying the *Logic of Collective Action,* expected collaborative processes to break down under the weight of free riders.[11]

There is mounting evidence, however, that they were all wrong, as new forms of collaboration bind people together in productive, social, and economic relations to produce and self-supply an increasing array of micro-products that meet their needs.[12] The ever-declining costs of digital production and distribution have thwarted the predicted dominance of large bundles of information goods.[13] Large numbers of producers have seen increasing returns by hooking up with large numbers of consumers to sell differentiated products in two-sided markets or, better still, by consumers becoming producers in technology-facilitated environments.[14] People are no longer passive participants in the economy, as they were in the media available in the 20th century.[15] When offered the opportunity to participate and communicate in the digital information age, people quickly accept.[16] The potential for collective action was far greater than anticipated.[17] As a result, group formation has been widespread due to the high value of heterogeneity and the ability of people to see and act on shared interests in a non-commodified digital space that facilitates communication.[18]

To fully understand the emergence of collaborative production, this paper extends familiar economic concepts to make an adjustment of the existing economic rationale for bringing information 'under a legal regime of property rights' to accommodate the notion of collaborative production.[19] Information products, in the traditional framework of market structure, are not simple private goods. Spectrum is a common pool resource and communications facilities are public goods.

In the structural view of industrial organization[20] and the institutional view of economics[21] adopted in this paper transaction costs play a key role. Structural analysis teaches that when basic economic conditions change as dramatically as they have in the past couple of decades, society should not be surprised to find fundamental changes in economic structure, conduct, and performance. Institutional economics focuses on cooperation and transaction costs as a challenge to economic systems.[22] Institutional analysis argues that in addition to the costs of production – the supply-side transformation costs in the economy – transactions are a central part of the total cost. Indeed, transaction costs are of equal, if not greater, importance than the transformation costs of production processes, especially when services become the focus of the economy. Above all, humans struggle "to solve the problems of cooperation so that they may reap

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[9] *See* ROBERT D. PUTNAM, BOWLING ALONE: THE COLLAPSE AND REVIVAL OF AMERICAN COMMUNITY (2000) (arguing that isolation and solitary activities had diminished the value of social capital).
[10] Peter Levine, *The Internet and Civil Society*, 20 REP. INST. PHIL. & PUB. POL'Y 1, 2 (2000).
[11] *See* MARCUR OLSEN, THE LOGIC OF COLLECTIVE ACTION (1965).
[12] *See* Arthur Lupia & Gisela Sin, *Which Public Goods Are Endangered? How Evolving Communications Technologies Affect The Logic of Collective Action*, 117 PUB. CHOICE. 315 (2003) (regarding collective action); *See also* COLEMAN & GOTZE, *supra* note 7.
[13] Hal R. Varian, *Copying and Copyright*, 19 J. ECON. PERSP. 121, 122 (2005).
[14] Glenn Ellison & Sara Fisher Elision, *Lessons about Markets from the Internet*, 19 J. ECON. PERSP. 139, 140 (2005).
[15] Kelly, *supra* note 1; Hof, *supra* note 4.
[16] *See* COLEMAN & GOTZE, *supra* note 7.
[17] *See* Lupia & Sin, *supra* note 12, at 315.
[18] The phenomenon includes everything from AOL buddy lists to MySpace friends, to the Wikis and collaborative activities. Kelly, *supra* note 1; Hof, *supra* note 4.
[19] This article uses the definition of intellectual property created by William Landes and Richard Posner: "ideas, inventions, discoveries, symbols, images, expressive works (verbal, visual, musical, theatrical), or in short any potentially valuable human product (broadly, "information") that has an existence separable from a unique physical embodiment, whether or not the product has actually been "propertized," that is, brought under a legal regime of property rights." WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW 1 (2003).
[20] FREDERIC SCHERER & DAVID ROSS, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE (3d ed. 1990).
[21] DOUGLASS C. NORTH, INSTITUTIONS, INSTITUTIONAL CHANGE AND ECONOMIC PERFORMANCE 3 (1990).
[22] Both sides of the debate over spectrum governance claim Coase as a forefather, in part because of his critique of the Federal Communications Commission management of spectrum. *See* R.H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1 (1959).

the advantages not only of technology, but also of all the other facets of human endeavor that constitute civilization."[23]

I. Analytic Framework

A. Traditional Public Goods

1. Characteristics of Traditional Public Goods

Economic analysis recognizes that under certain conditions competitive markets do not produce socially desirable outcomes.[24] In the case of public goods and externalities, the problem is not a lack of competition, but the inability of profit-driven market transactions to produce the goods or capture the values that best serve society. Markets with externalities and markets with public goods are "not likely to allocate resources efficiently, even though they might otherwise be competitive."[25] Externalities occur when the market price does not reflect the costs or benefit to the consumer or producer or others, not party to the transaction.[26] Public goods benefit all consumers, "even though individuals may not pay for the costs of production."[27] Both externalities and public goods affect the invisible hand theory in that it "may not guide the market to an economically efficient amount of production."[28]

These market failures occur where goods lack the critical characteristics that enable transactions in private property. (See Exhibit 1). In the neoclassical paradigm, scarcity is about rivalry and property is about exclusion. As Landes and Posner note, "[a] property right is a legally enforceable power to exclude others from using a resource."[29] A private good is **rivalrous** since "consumption by one person reduces the quantity that can be consumed by another person"[30] and **exclusive** since "consumers may be denied access."[31]

The central claim for the superiority of private goods is that where resources are rivalrous or subtractable, efficiency requires they be devoted to their highest valued use.[32] Exclusion gives the owner of the resource the incentive to husband the resource, especially where investment is necessary to replenish it.[33] Market allocation solves the subtractability problem by directing resources to their highest value uses.[34] The classic "tragedy of the commons" is the case where the failure to grant rights of exclusion leads to either under investment in the resource or overuse.[35]

When rivalry and excludability conditions are absent, the provision of goods in markets becomes problematic, particularly for private firms. **Nonrivalry** occurs where increased consumption of a good by one person does not decrease the amount available for consumption by others.[36] Here allocation does not promote efficiency, since consumers do not consume anything in the traditional sense and there is no scarcity to allocate. **Nonexcludability** means the consumers are not economically prevented from consumption either because the producer surplus is eaten up by the difficulty of exclusion or compensation cannot be

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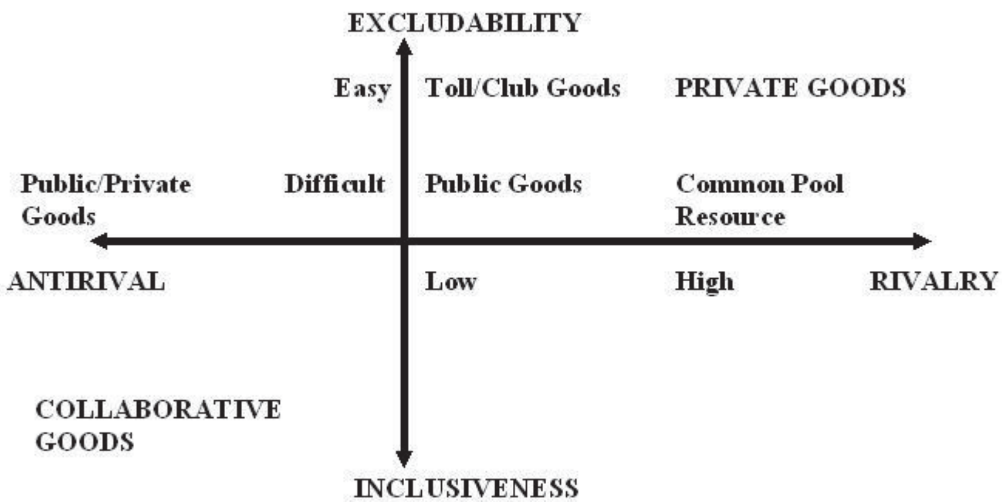
[23] North, *supra* note 21, at 118-33.
[24] David Besanko & Ronald R. Braeutigam, Microeconomics: An Integrated Approach 727 (2002).
[25] *Id.*
[26] *Id.*
[27] *Id.*
[28] *Id.*
[29] Landes & Posner, *supra* note 19, at 12.
[30] Besanko & Braeutigan, *supra* note 24, at G-7.
[31] *Id.*
[32] John B. Taylor, Economics 184 (1998).
[33] *Id.* at 48.
[34] *Id.* at 184.
[35] *Id.* at 481.
[36] *Id.* at 407.

extracted from "free riders."[37] Exclusion is valueless and there is little incentive to invest.

This gives rise to the familiar typology of goods shown in the upper right hand quadrant of Exhibit 1. Note that I present the two characteristics as continua to underscore the absence of sharp dividing lines. Goods are more or less rivalrous and excludable. There is no precise point where they pass from being a private good to a public good.

Exhibit 1: Characteristics Of Collaborative Goods



A public good exhibits *nonrivalry in consumption* and *nonexcludability*.[38] When producers cannot exclude individuals from consuming their good, the individuals using the good for free may withhold their support for the good, seeking a free ride. Where the costs of exclusion are high, the cost may outweigh the value of the good. This prevents producers from providing public goods, even when those goods are beneficial to the public.

There are additional problems in private provision. Transactions may not take place for a variety of reasons such as excessive transaction costs or the inclination to try to "hold-up" transactions, seeking a larger share of the rents.[39] There is the "tragedy of the anti-commons" – the excessive fragmentation of property rights preventing transactions from taking place.[40] In this case, which might be considered a condition of excessive rivalry, producers and consumers cannot execute transactions as the institutional arrangement creates such huge transaction costs and problems.

Common pool resources (CPR) and their associated governance rules have also received increasing

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[37] *Id.* at 407.
[38] *Id.* at 406.
[39] ERIK G. FURUBOTN & RUDOLF RICHTER, INSTITUTIONS AND ECONOMIC THEORY: THE CONTRIBUTION OF THE NEW INSTITUTIONAL ECONOMICS 131, 139 (2000).
[40] Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621, 622 (1998).

attention.[41] These resources are non-excludable, but they are rivalrous. The solution to the problems associated with common-pool resources is not necessarily private property, though. "If exclusion costs are comparatively high, common ownership solutions may be preferable."[42] The possibility of co-existence of different governance regimes is particularly important for common-pool resources because many CPRs incorporate characteristics of private and public goods.[43] In some instances, this is known as the "comedy of the commons."[44] The "comedy of the commons" is the opposite of the "tragedy of the commons" – the notion that users of commonly held property such as forests, fisheries, and most notably air, work together to ensure that overexploitation does not occur.[45]

2. Traditional Goods and the Technology Sector

Traditional public goods have played a particularly large role in the communications space. For centuries, society has treated communications networks as infrastructural, public goods. However, the distinctively American approach to the provision of these projects was to blend private capital with public interest obligations. Deemed to be "affected with the public interest," privately built communications networks first took the form of common carrier regulation and later took on price, quantity, and entry regulation.

Typically, infrastructure is a large investment that affects many aspects of the economy and exhibits substantial economies of scale.[46] Costs decline as more people use the infrastructure and the value of the economic activity it supports expands. Given the size of the investment and the need to expand consumption over a long period, it is difficult for private developers to realize an adequate return on such projects. The number of suppliers is likely to be limited. A natural monopoly, or at best a duopoly, develops – that is if any producer enters the market.

As an empirical matter, there are five clear linkages between communication infrastructure and public goods. First, infrastructure generates positive externalities by stimulating economic activity; public goods capture externalities that private, market transactions cannot.[47] Second, as a practical matter, for most of their economic life, infrastructure projects tend to be un-congested and non-rivalrous, especially in low-density, low-income areas.[48] Third, traditionally, society makes communications infrastructure a matter of public policy because private developers are unlikely to provide needed communication infrastructure adequately.[49] Fourth, because communications infrastructure networks connect people, the value of the network grows as more people connect to it.[50] Finally, communications networks traditionally receive special treatment from the government with franchises, subsidies, or special contracts.[51]

B. Collaborative Goods

Although it is certainly possible to analyze communication and information goods in the traditional

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[41] *See, e.g.*, Charlotte Hess & Elinor Ostrom, *Artifacts, Facilities, and Content: Information as a Common-Pool Resource*, 66 LAW & CONTEMP. PROBS. 111 (2001).
[42] FURUBOTN & RICHTER, *supra* note 39, at 101.
[43] *Id.* at 102.
[44] *See* Carol Rose, *The Comedy of the Commons: Commerce, Custom and Inherently Public Property*, 53 U. CHI. L. REV. 711 (1986).
[45] ELINOR OSTROM, ROY GARDNER & JAMES WALKER, RULES, GAMES & COMMON-POOL RESOURCES bookjacket (1994).
[46] ALFRED. E. KAHN, THE ECONOMICS OF REGULATION: PRINCIPLES AND INSTITUTIONS 11 (1988).
[47] TAYLOR, *supra* note 32, at 598.
[48] Brett M. Frischmann, *An Economic Theory of Infrastructure and Commons Management*, 89 MINN. L. REV. 917, 952 (2005).
[49] *Id*.
[50] BESANKO & BRAEUTIGAM, *supra* note 24, at 200.
[51] For an account of the early history of the telegraph and telephone in America which includes examples of various types of special treatment, *see* ALAN STONE, PUBLIC SERVICE LIBERALISM: TELECOMMUNICATIONS AND TRANSITIONS IN PUBLIC POLICY (1991).

framework of public goods, in the emerging information economy there must be an expansion of the underlying economic concepts used to define these goods.[52] The emergence of collaborative production on a large scale suggests something more, something different from common-pool resources and public goods.

Similar to public goods which represent a collective decision to provide an input for communications infrastructure, collaborative production entails a production process in which private appropriation of shared resources is accomplished.[53] However, collaborative production is a continuous direct relationship between producers outside the traditional market place. It is genuine joint production, not the collective supply or management of an input for private appropriation.

Collaborative production goods exhibit traits of anti-rivalry and inclusivity. The key characteristics of collaborative production goods occur where having numerous producers participate in the production of the goods increases its value and where the value of the good goes up as the number of people who use it increases. All three examples, discussed in greater detail later in this paper, wireless mesh networks, open source software and peer-to-peer networks exhibit these characteristics.[54]

Anti-rivalry occurs when the use and/or sharing the production of the good by one person increases the value of the good to others.[55] **Inclusiveness** occurs when the value of a good increases as the number of people using and/or producing the good increases.[56] Eric von Hippel's work on user driven innovation and free revealing reinforces the distinction between anti-rivalry and inclusiveness.[57] He identifies a **private/collective** good as a good for which individuals volunteer to support the supply of the good to the community of producers.[58] This provides a nuanced difference from a common pool resource in that an independent private action produces the resource for the community.[59] Innovators freely reveal private effort because they can "*inherently* obtain greater private benefits than free riders."[60]

In the information economy, just as it is necessary to distinguish between anti-rivalry and inclusiveness, it is also necessary to distinguish between inclusiveness and **network effects.** Network effects, also known as demand side economies of scale, occur when the costs of producing or the benefits of consuming a good spill over onto those who are producing or consuming the good, beyond the transaction.[61] The benefits of the network effect accrue to members of the network, directly or indirectly. The classic example of a direct network effect is a telephone. The value of the telephone grows as the number of people on the network increases due to the increasing number of reachable people. The classic example of an indirect network effect is software. The value of an operating system goes up as the number of people using it increases because more companies produce applications for it. Although there is no direct connection between the members of the network, the benefits still accrues to network members.

Frischmann argues for an additional distinction "between network effects and infrastructure effect."[62] The externalities of public and social infrastructures are diffuse because they "positively affect the

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[52] *See* MARK COOPER, MAKING THE NETWORK CONNECTION, IN OPEN ARCHITECTURE AS COMMUNICATIONS POLICY (Mark Cooper ed. 2004).
[53] WEBER, *supra* note 5.
[54] Although I believe the two characteristics are separate, some believe the two are the same. *See id*.
[55] *Id*.
[56] CARL SHAPIRO & HAL VARIAN, INFORMATION RULES 178-84 (1999) (emphasizing demand side economies of scale and network externalities, which drives toward the concept of inclusiveness argued here).
[57] ERIC VON HIPPEL, DEMOCRATIZING INNOVATION 91 (2005).
[58] *Id*.
[59] *Id*.
[60] *Id*.
[61] BESANKO & BRAEUTIGAM, *supra* note 24, at 199-200.
[62] Frischmann, *supra* note 48, at 973.

utility of nonusers, that is, members of society who are not using the infrastructure itself also benefit."[63] Frischmann gives both a social and economic example of these diffuse externalities.[64] Socially, the increase in political discourse among Internet users also benefits non-users.[65] Economically, the increase of fertilizer due to an irrigation project increasing agricultural output affects distant fertilizer plants.[66]

David Reed describes two characteristics of adaptive network architectures in the spectrum that parallel the concepts of anti-rivalry and inclusiveness.[67] The first characteristic, cooperation gain, is the focal point of his analysis.[68] Cooperative gain, much like the anti-rivalry principle identified earlier, is the phenomenon where "[c]ompared to systems of dedicated, isolated links, networks provide much more transport capacity at much greater transport efficiency… [creating] major economic benefits."[69] The second characteristic is network optionality.[70] Network optionality, much like the inclusiveness principle discussed above, comprises two network externalities.[71] First, the "system-wide option value of flexibility in a network scales proportionally to the square of the number of nodes."[72] Second, "the option value that accrues due to the ability to dynamically assign capacity depending on shifting demand can increase super-linearly as the number of cooperating nodes in a network."[73] Yochai Benkler illustrates this when he states that the sharing of spectrum points toward the gain from network optionality by stressing the value of expanding "the set of usable combinations."[74] Property rights are inefficient in the dynamic allocation of spectrum, Benkler argues, because "[p]roperty rights in bandwidth inefficiently fence a sub-optimal resource boundary."[75]

Exhibit 1 locates these characteristics of anti-rivalry and inclusiveness as extensions of the existing dimensions. In the rivalry dimension, we start at private goods that exhibit high rivalry, which means that use by one subtracts from the use by another. We move to public goods, which exhibit low rivalry, where use by one does not subtract from use by the other. For anti-rivalry goods, we hypothesize the opposite effect, use by one adds to the potential for use by another. In the excludability dimension, we start with private goods, where it is easy to keeping people out. We move to public goods, where excludability is difficulty. For inclusive goods, we hypothesize to the opposite effect – the benefit of pulling people in.

Information goods are extremely good candidates to be collaborative goods because information is "an extreme nonrival good" and an "unusually" non-exclusive good.[76] A person can only own information if that person keeps the information to himself; once that information has been released to the public the person who distributed cannot control who else gains the information.[77]

Although information is hard to control, that alone does not guarantee collaboration. Collaborative

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63 *Id.* at 973-74.
64 *Id.*
65 *Id.*
66 *Id.*
67 David P. Reed, *Comment for FCC Spectrum Policy Task Force on Spectrum Policy*, ET Docket No. 02-135, July 8, 2002, at 10.
68 *Id.*
69 *Id.*; Spectrum is a highly developed example analyzed in detail by Reed. He identifies how, as opposed to property rights that are to combat the "tragedy of the commons" by preserving property, "spectrum capacity increases with the number of users, and if proportional to N, each new user is self-supporting!" David P. Reed, *How Wireless Networks Scale: The Illusion Of Spectrum Scarcity*, Silicon Flatirons Telecommunications Program, Boulder Colorado (March 5, 2002).
70 Reed, *supra* note 67.
71 *Id.*
72 *Id.*
73 *Id.*
74 Yochai Benkler, *Open Spectrum Policy: Building the Commons in Physical Infrastructure*, 23, *available at* http://www.newamerica.net/Download_Docs/pdfs/Doc_File_122_1.pdf.
75 *Id.*
76 RISHAB AIYER GHOSH, WHY COLLABORATION IS IMPORTANT (AGAIN), IN CODE: COLLABORATIVE OWNERSHIP AND THE DIGITAL ECONOMY 1-2 (Rishab Aiyer Ghosh ed. 2005).
77 *Id.*

production is not successful just because of weak property rights; there must also be benefits to those that participate.[78] Collaborative production must increase value to the group. Collaborative production must motivate individuals to participate voluntarily as the individuals capture non-rivalrous benefits. It must allow free revealers to recognize that the potential gains of opportunistic behavior will evaporate if the cooperative behavior breaks down. Cooperation becomes the rule, rather than the exception.

The challenges to collaborative goods are also greatly different from those of public goods. In the world of private goods, the problem is the inclination to free ride, to withhold payment or support for the provision of public goods, or to overuse the common pool resource, even though that may be bad for the public. In the world of collaborative goods, the challenge is to understand the willingness of producers to support or freely reveal innovations that enhance shared benefits, even though they do not appear to capture as much private value as they could by withholding.

II. Sources of Economic Advantage for Collaborative Production in the Digital Age

A. Technological Conditions

In order for anti-rivalry and inclusiveness to dominate, communications and information must be available; for example, the areas examined in this paper have been deeply affected and benefited mightily from the revolution in computer and communications capacity. Of equal importance are the principles that organize interconnected computers into powerful networks; for example, distributed computer capacity able to communicate at high speeds and low cost is a platform that allows more readily for collaborative production.[79]

Historically, dramatic changes in communications and transportation technology have affected society deeply.[80] However, the convergence of a highly interrelated set of activities in the communications, computer, and information industries in the late twentieth century created not merely a new environment in which information is produced and distributed, but also a revolutionary change in a wide range of economic activities.[81] The digital communications platform "links the logic of numbers to the expressive power and authority of words and images. Internet technology offers new forms for social and economic enterprise, new versatility for business relationships and partnerships, and a new scope and efficiency for markets."[82]

Because society can distribute computing intelligence widely and quickly, society has transformed interactivity.[83] "As rapid advances in computation lower the cost of information production and as the cost of communications decline, human capital becomes the salient economic good involved in information production."[84] Users become producers as their feedback rapidly influences the evolution of information products. Society has also been transformed as the ability to embody knowledge in tools and software

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[78] OSTROM, GARDNER & WALKER, *supra* note 45, at 220.
[79] M. CASTELLS, THE INTERNET GALAXY – REFLECTIONS ON THE INTERNET, BUSINESS, AND SOCIETY 28 (2001).
[80] FRANCES CAIRNCROSS, THE DEATH OF DISTANCE (2001).
[81] We can track the technological transformation across all dimensions of society [M. Cooper, *Inequality In Digital Society: Why The Digital Divide Deserves All The Attention It Gets*, 20 CARDOZO ARTS & ENT. L. J. 73, 93 (2002)], including the economy [BRIE-IGCC E-CONOMY PROJECT, TRACKING A TRANSFORMATION: E-COMMERCE AND THE TERMS OF COMPETITION IN INDUSTRIES (2001)], the workforce [I. H. Simpson, *Historical Patterns Of Workplace Organization: From Mechanical To Electronic Control And Beyond*, CURRENT SOCIOLOGY, 47 (1999); *see also* B. BLUESTONE & B. HARRISON, GROWING PROSPERITY: THE BATTLE FOR GROWTH WITH EQUITY IN THE TWENTY-FIRST CENTURY (2001)], the polity [E. C. KAMARCK & J. S. NYE JR. EDS., GOVERNANCE.COM: DEMOCRACY IN THE INFORMATION AGE (2002)], and civic institutions [A.L. SHAPIRO, THE CONTROL REVOLUTION: HOW THE INTERNET IS PUTTING INDIVIDUALS IN CHARGE AND CHANGING THE WORLD WE KNOW (1999)].
[82] ERIK BRYNJOLFSSON & BRIAN KAHIN, UNDERSTANDING THE DIGITAL ECONOMY: DATA, TOOLS AND RESEARCH 1 (Erik Brynjolfsson & Brian Kahin eds. 2000).
[83] CASTELLS, *supra* note 79.
[84] Y. Benkler, *Coase's Penguin, Or Linux And The Nature Of The Firm*, 2 (2001), *available at* http://www.law.duke.edu/pd/papers/Coase's_Penguin.pdf.

lowers the cost of transfer dramatically.[85]

Recent analyses of technological innovation have also provided strong evidence that the digital communications platform transformed the very fabric of the innovation process.[86] The technological revolution altered the information environment to make distributed solutions more feasible by fostering the uniquely user-focused character of the communications-intensive Internet solution. Technological advance is also making user-based design an attractive option.[87] It allows individuals to participate in task portioning and decision-making.[88]

The very technologies at the core of this revolution reinforce the dynamic of this change because they are platforms within networks. "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."[89] They are important because there are strong complementarities between the layers and each layer sustains broad economic activity in the layer above it.[90]

Communications and computer industries have always exhibited network effects and strong economies of scale.[91] Digitization reinforces these economic characteristics because economies of scope reinforce economies of scale. The embedded architecture of the network is at least as important as the technological characteristics. The technologies themselves would not be as powerful nor would the effect on the rest of society be as great if the platform had not evolved as an "ultrarobust" network.

B. Economic Advantages

In the digital environment, as described in Exhibit 2, there are three economic advantages created by collaborative production: 1) a higher level of sharing resources lowers the transformation costs of production; 2) transforming consumers into producers reduces the gap between consumers and producers; and 3) there is a greater value on the demand-side as participants facilitate and tap the energy of groups forming networks.

1. Supply-Side Transformation Resource Savings

The advantage in the transformation process rests on two factors. First, each set of activities accomplishes greater coordination by applying a combination of technological and human coordination.[92] For instance, mesh wireless communications rely more on embedding cooperation in the technology: the algorithms and protocols of communications devices. Open source, in contrast, relies more on human cooperation, greatly enhanced by digital communications. Peer-to-peer networks made up of non-technologists stand between the two. Technology does much of the work, but the functioning of the network requires the cooperation of the people using it. Most importantly, these networks survive with varying levels of human

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[85] "Advances in scientific understanding decrease the costs of articulating tacit and context-dependent knowledge and reduce the costs of technology transfer. Further, such knowledge can be embodied in tools, particularly software tools, which make the knowledge available to others cheaply and in a useful form." ASHISH. ARORA ET AL., MARKETS FOR TECHNOLOGY: THE ECONOMICS OF INNOVATION AND CORPORATE STRATEGY 112, 113 (2001).
[86] This is also called "the changing technology of technical change." *Id.* at 112.
[87] Eric von Hippel, *Economics Of Product Development By Users: The Impact Of 'Sticky' Local Information*, 44 MGMT. SCI. 629, 642 (1998).
[88] ARORA ET AL., *supra* note 85.
[89] Shane Greenstein, *The Evolving Structure of the Internet Market*, *in* UNDERSTANDING THE DIGITAL ECONOMY, *supra* note 82, at 155.
[90] *See* SHAPIRO & VARIAN, *supra* note 56, at 9-15.
[91] *Id.* at 22-23.
[92] *See* Section IV, *infra,* for a description.

cooperation and skill.

Exhibit 2: Sources of Comparative Advantage of Collaborative Production

ACTIVITY	SHARED RESOURCE	PROCESS	BENEFIT
SUPPLY SIDE TRANSFORMATION RESOURCE SAVINGS			
Mesh Networks	Spectrum	Embedding Coordination in algorithms	Dynamic occupation of spectrum
Open Source software	Code	Embodied knowledge in software	Exploiting rich information in real time
Peer-to-Peer	Storage, Bandwidth, Content	Torrenting Viral communications	Reduction in cost and expansion of throughput Broad exchange, Collaboration
TRANSACTION COST REDUCTION			
All	Local knowledge	Consumer as Producer	Fit between consumer needs and output
DEMAND-SIDE VALUE CREATION			
All	Network	Self-organizing	Increased option value

Second, in each case, networks share critical resources: spectrum, code, storage, and bandwidth.[93] Sharing requires a process, a principle of cooperation that organizes the critical factors of production. The sharing of resources creates significant efficiencies for the networked activities and confers benefits to the collaborating parties. The capacity of the network expands. When the benefits are larger, the cost is lower. When it is easy to communicate, collaboration is more likely.

2. Transaction Cost Reductions

Collaborative production also produces an economic advantage because it transforms consumers into producers.[94] Reducing or removing the distinction between user and producer results in substantial transaction cost savings. The distance shortens between what producers produce and what consumers consume because the consumer turned producer knows what he wants more than a producer who is not a consumer. The consumer's and producer's interests are identical as they are the same person.

Users know what they need and want. Transferring that knowledge to producers creates inefficiency. Producers who are also users and volunteer for tasks that interest them inherently understand the production problem more clearly and can produce for their needs more easily instead of for the masses.

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[93] *Id.*
[94] *Id.*

They have the locally specific knowledge necessary to solve problems.[95] There is also an agency problem when consumers are not producers.[96] When producers are separate from consumers, the producer may not be able to meet the needs of individual consumers precisely. However, when the developer is also the consumer, he will act in his own best interest when producing a product.[97]

3. Demand-Side Value Creation

Collaborative production creates economic advantage on the demand-side due to group formation.[98] This is the demand-side since the size of the network, the number of network members that are reachable, and the pattern of interactions dictate the value of the network to the members. As the value of the network increases, the possibilities for communications (and therefore commerce) also increase. As consumers decide which group, and therefore network, to join they also change the group to fit their needs. This increases the value of the group to the consumer even more.

Reed identifies three types of networks that create value (see Exhibit 3).[99] First, there are one-way broadcast networks.[100] Also known as the Sarnoff "push" network, the value of one-way broadcast networks is equal to the number of receivers that a single transmitter can reach.[101] An example of a one-way broadcast network is the wire service.[102] Second, there are Metcalfe networks.[103] In a Metcalfe network, the center acts as an intermediary, linking nodes.[104] Classified advertising is an example of the Metcalfe network.[105] Third, there are Group Forming Networks, also known as Reed Communities.[106] In this network, collateral communications can take place.[107] The nodes can communicate with one another simultaneously.[108] Chat groups are the classic example of this type of network.[109]

Collateral communications expands the possible connections dramatically. Network optionality, when realized in group-formation, generates much greater value than traditional models. As more people join the network, the value of the network increases.[110] In addition, networks that "support the construction of communicating groups create value that scales *exponentially* with network size, i.e. much more rapidly than Metcalfe's square law… [called] Group Forming Networks."[111]

Exhibit 3 shows how the value of being part of the network scales as the number of members increases. The Sarnoff value is N. The Metcalfe value is N^2. The Reed community value is 2^N. The key difference between the Metcalfe network and the Group Forming Network is multi-way communications. Group Forming Networks use group tools and technologies such as chat rooms and buddy-lists that "allow small or large groups of network users to coalesce and to organize their communications around a common interest, issue, or goal."[112] The exponentiation increases value very quickly and may cause the number of

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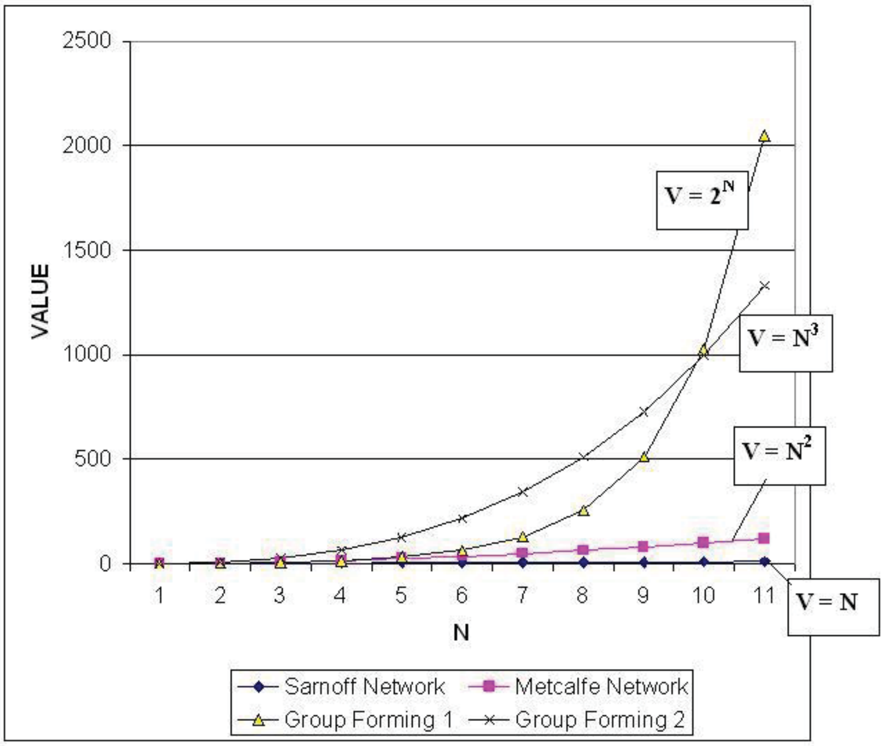
95 ERIC VON HIPPEL, OPEN SOURCE SOFTWARE PROJECTS AS USER INNOVATION NETWORKS (2002); PERSPECTIVES ON FREE AND OPEN SOURCE SOFTWARE 271 (Joseph Feller et al. eds. 2005).
96 *Id.* at 277.
97 VON HIPPEL, *supra* note 57, at 276-77.
98 Section IV, *infra*, describes the value of group formation in each of the three areas studied in this paper.
99 *See* David P. Reed, *That Sneaky Exponential – Beyond Metcalfe's Law to the Power of Community Building* (Spring 1999), *available at* http://www.reed.com/Papers/GFN/reedslaw.html.
100 *Id.*
101 *Id.*
102 *Id.*
103 *Id.*
104 *Id.*
105 *Id.*
106 *Id.*
107 *Id.*
108 *Id.*
109 *Id.*
110 *Id.*
111 *Id.*
112 *Id.*

connections/communications to exceed the ability of individuals to maintain them. Thus, it is a theoretical upper limit. On the other hand, as Reed points out, the formation of even a small subset of the theoretically possible groups would dramatically increase the value of the network - N^3 in Exhibit 3. Even if not all groups form, the potential value in the option to form groups is higher. The critical point is that to capture the value of group forming networks, the members of the network must have the freedom to self-organize groups. With that freedom, they create the groups of greatest value to the users.

Exhibit 3: Value of Traditional and Group Forming Networks



Source: David Reed, "That Sneaky Exponential – Beyond Metcalfe's Law to the Power of Community Building," *Context,* Spring 1999

C. Cooperation In A New Age Of Collective Action

Since cooperation lies at the core of the emerging mode of production, it is important to understand why a new solution to the challenge emerges. Conventional collective action arguments say that a large group is less likely to generate collective goods because each member would receive such a small fraction of the benefit that they would lose their desire to produce collectively. [113] However, with the emerging collaborative production the opposite is true as seen in open-source software: the larger the group connected by the Internet, the more likely it is to have the motivation and resources to create code.[114] User-driven

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[113] WEBER, *supra* note 5, at 155.
[114] *Id.*

innovation causes individuals to volunteer, particularly the core group of lead users.[115]

The existence of heterogeneous resources available in the network definitely improves the efficiency of collaborative responses, but this may not be a necessary condition. The critical condition is the ease of communications. The Internet, for instance, spawned innovation, as participants of group projects were able to work together over long distances and share their specific skills in a "seamless process."[116]

New communication technologies allow for reduction in cost of sending information long distances, increase "noticeability, and make ineffective communicative networks effective."[117] Communications technology allows large numbers of people with common interests to interact and share information "in a way that undermines many widely held beliefs about the logic of collective action."[118]

It may well be that the literature on collective action was always too pessimistic.[119] For example, the literature that stresses the tragedy of the commons assumes "individuals do not know one another, cannot communicate effectively, and thus cannot develop agreements, norms, and sanctions" was never correct in physical space and certainly is not correct in cyberspace.[120] The ability to communicate changes everything – especially when a collective payoff flows from cooperation.

In addition, the recognition of shared interest plays a key role in establishing the necessary cooperation. When a monitored and sanctioned system is agreed upon, it "enhances the likelihood that agreements will be sustained, they are capable of setting up and operating their own enforcement mechanism."[121] Due to the benefits received from cooperation, the effect of breaking those agreements may deter those inclined to break the agreements, as it will affect not only the individual, but also the group as a whole.[122] Thus, even prior to the advent of digital communications platforms, the ability to communicate and exchange information was central to the ability to organize around shared interests and take collective action, but the capacity to do so has been fundamentally enhanced by the recent technological revolution.

III. INTERNAL ORGANIZATION OF DIGITAL PRODUCTION

A. Supply-side Resource Savings

1. Open Mesh Networks

Mesh networks in the spectrum commons exhibit the advantages of collaborative production on the supply side.[123] As people add devices, the total capacity of the system increases due to those devices routing communications throughout the network (see Exhibit 4).[124] Depending on how well these devices share the network traffic, the capacity of each device may decline, but at a slower rate than if they did not share communications.[125] If the graph showed a cost curve, it would show that the cost per unit of capacity is lower for both total capacity and on a per station basis in the repeater network.[126]

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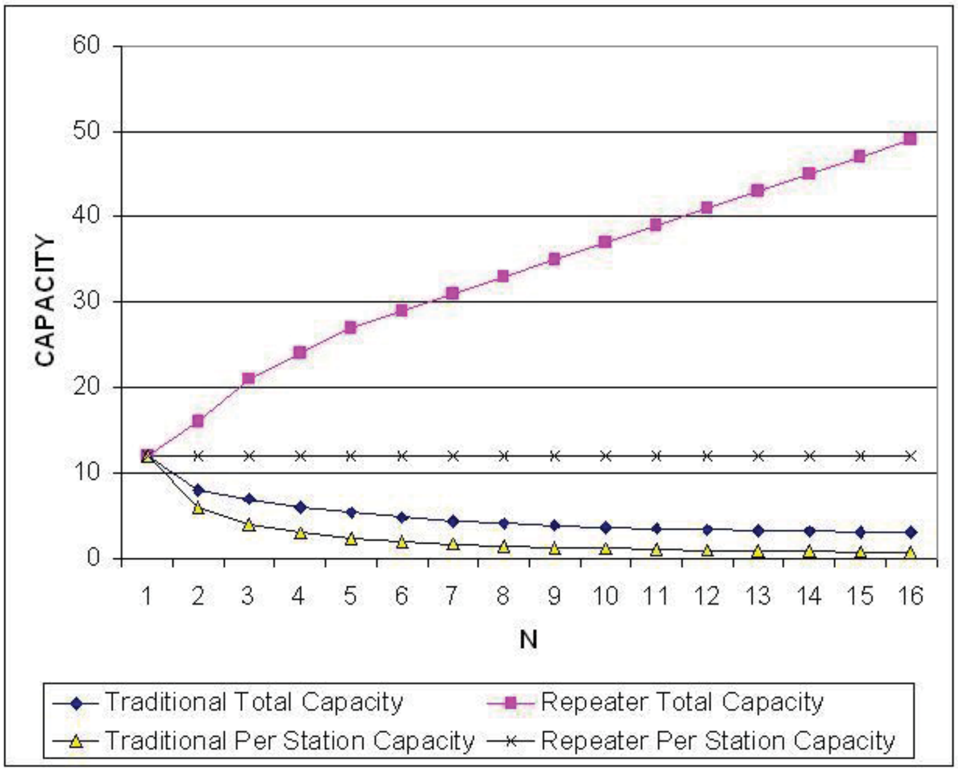
[115] *See generally* VON HIPPEL, *supra* note 57.
[116] WEBER, *supra* note 5, at 83-84.
[117] Lupia & Sin, *supra* note 12, at 329.
[118] *Id.*
[119] *See generally* OSTROM ET AL., *supra* note 45, at 319.
[120] *Id.*
[121] *Id.* at 220.
[122] *Id.* at 296.
[123] Reed, *supra* note 69.
[124] *Id.*
[125] *Id.*
[126] *Id.*

The technologies at the heart of the digital revolution are also at the heart of the deployment of open wireless networks in the spectrum commons. The potential spectrum carrying capacity has been the direct beneficiary of the convergence of progress in digital technology and the institutional development of networks.[127] When users add radios that help by cooperating in receiving and forwarding signals, i.e. act as repeaters, carrying capacity of the network increases.[128] Smart nodes get their expanding brainpower from decentralized computational capacity to communicate seamlessly, utilizing embedded coordination protocols.[129]

Exhibit 4: Spectrum Capacity In Traditional And Repeater Networks



Source: D. P. Reed, "How Wireless Networks Scale: The Illusion of Spectrum Scarcity," Silicon Flatirons Telecommunications Program, March 5, 2002, pp. 10, 14.

Smart technologies in mesh networks cooperating to deliver messages also show the beginning of anti-rivalry characteristics.[130] The ability of each node to receive and transmit messages, even when they are neither the origin nor the destination, expands the capacity of the network. This intelligence is the key to mesh networks' immense capacity.[131]

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[127] "There is a 'new frontier' being opened up by the interaction of digital communications technology, internetworking architectures, and distributed, inexpensive general purpose computing devices." Reed, *supra* note 67, at 2.

[128] R. J. BERGER, *No Time for a Big Bang: Too Early to Permanently Allocate Spectrum to Private Property*, CENTER FOR GLOBAL COMMUNICATIONS 7 (2003).

[129] Reed, *supra* note 67.

[130] Reed, *supra* note 69.

[131] L. Berlemann, S. Mangold & B.H. Walke, *Policy-based Reasoning for Spectrum Sharing in Cognitive Radio Networks*, IEEE

The spectrum commons in which these networks exist exhibits the characteristic of inclusiveness, since the more nodes on the network, the greater the value to users.[132] The denser the nodes in the commons, the greater is the commons' communications capacity.[133] The combination of digital technology and network organization has turned the old logic on its head; adding users on a mesh network improves performance.[134] Mesh networks allow devices to share their resources dynamically, allowing more communications to take place with less power.[135]

However, even with new technology, there is still the challenge of how to ensure cooperation among users. Since cooperation is the key to the capacity gain, if users chose not to cooperate, the mesh network will not work.[136] Therefore, more devices are transitioning to "embed coordination" to ensure cooperation.[137] For example, radios become smart by embedding intelligence – algorithms – that take on the functions necessary to transmit a signal after listening to the spectrum and finding available frequencies to use and determining the power necessary.[138]

2. Open Source

The digital environment is particularly challenging for the production of goods used to produce other goods and services, called functional information goods, such as software. This is due in part to people not consuming functional goods for their intrinsic value, like viewing a movie, but to meet other needs, like writing a document with word processing software. Because software is a tool that will be used by different people in different ways under different circumstances, it is more difficult to design and build than cultural goods.[139]

Just as mesh networks defy the conventional wisdom of collaboration, so does open source. "[T]he sharing of rich information in real time" deeply affects the basis for collective action "because (a) constituents have symmetry of absorptive capacity, and (b) software itself is a capital structure embodying knowledge."[140] The capacity of groups to produce open source software increases due to the sharing and exchange of information between humans much as occurs between devices in mesh networks: collaboration increases capacity and lowers cost (see Exhibit 5).[141]

The increase in low cost communications and distributed computer intelligence has a particularly powerful impact on the ability to produce information products where users are technically savvy.[142] With a vast array of diverse individuals available to address the complex problems of producing software, the human resource pool is expanded. By drawing from this pool, there is an increase of the chances that someone, somewhere will have the necessary skills to solve a problem. By keeping systems open and

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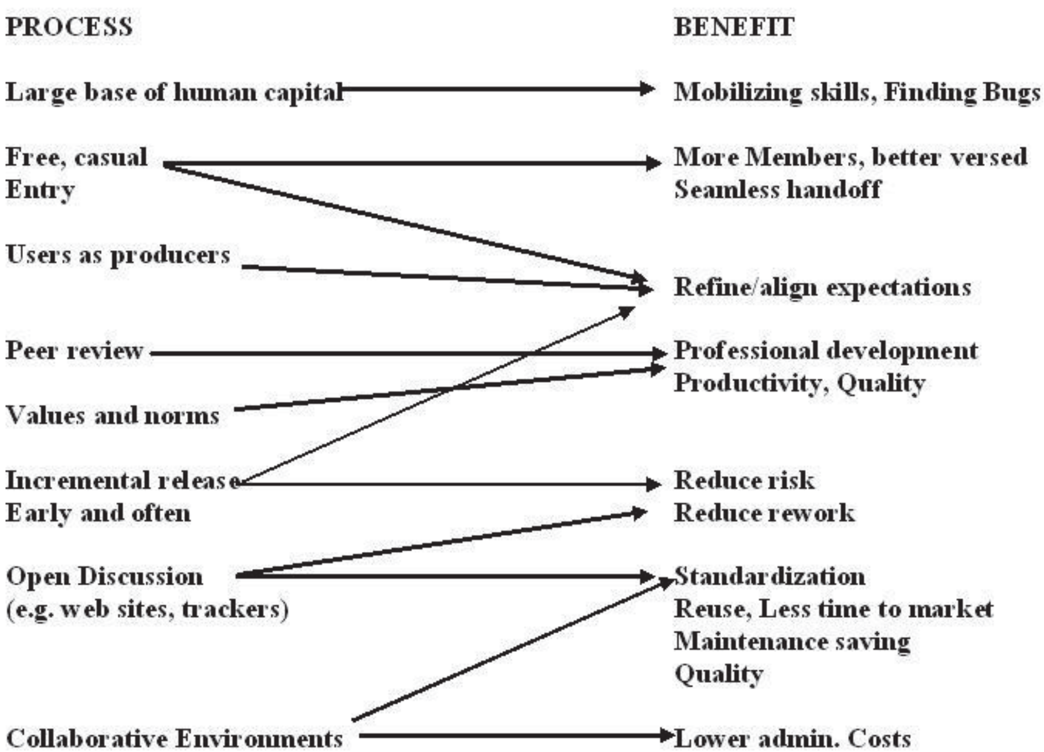
Int'l Symp. on New Frontiers in Dynamic Spectrum Access Networks (Nov. 8-11, 2005).
[132] *See* Reed, *supra* note 99.
[133] Reed, *supra* note 67.
[134] *Id*.
[135] Reed, *supra* note 69.
[136] T. X. Brown, *An Analysis of Unlicensed Device Operation in Licensed Broadcast Service Bands,* IEEE Int'l Symp. on New Frontiers in Dynamic Spectrum Access Networks (Nov. 8-11, 2005) (noting the superior characteristics where participation is broad); Lehr and Crowcroft, *Managing Shared Access to a Spectrum Commons*, IEEE Int'l Symp. on New Frontiers in Dynamic Spectrum Access Networks (Nov. 8-11, 2005) (emphasizing the importance of requiring participation).
[137] Berleman, *supra* note 131.
[138] Reed, *supra* note 67.
[139] Srdjan Rusovan, Mark Lawford & David Lorge Parnas, *Open Source Software Development: Future or Fad?, in* PERSPECTIVES ON FREE AND OPEN SOURCE SOFTWARE, *supra* note 95 (describing the complexity problem facing software); s*ee also* WEBER, *supra* note 5, at 61-62.
[140] Giampaolo Garzarelli, *Open Source Software and the Economics of Organization*, ii (April 30, 2002), *available at* http://opensource.mit.edu/papers/garzarelli.pdf.
[141] WEBER, *supra* note 5, at 81.
[142] Josh Lerner & Jean Tirole, *Some Simple Economics of Open Source,* 50 J. OF INDUS. ECON. 197, 202 (2002) (describing "the third era" of open source as "the widespread diffusion of Internet access early in the 1990s led to a dramatic acceleration of open sources activities.").

promoting interoperability, the chances increase that the project will have a solution to any problems encountered. While the decentralized approach encourages multiple attempts to solve a problem, there is also the advantage of quickly communicating solutions so that everyone can move to the next problem after a solution is found.[143]

Exhibit 5: Benefits of Open Source



3. Peer-to-Peer Networks

As hardware and communications costs declined and larger, faster PC's penetrated the market and larger, video files began to move over broadband connections, both the central servers and backbone capacity of the Internet quickly became economic bottlenecks.[144] The evolving infrastructure of the Internet made it inevitable that users would eventually develop software to escape this bottleneck by tapping into the abundant resources available on the network's edges.[145] By building a multi-level redundancy and additional communication points into the network, the network becomes more robust and scalable.[146]

Peer-to-peer networks are part of the evolving communications infrastructure.[147] The immense

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[143] JOSEPH FELLER & BRIAN FITZGERALD, UNDERSTANDING OPEN SOURCE SOFTWARE DEVELOPMENT 86 (2002).
[144] *See* Brief of American Civil Liberties Union as Amicus Curiae Supporting Respondents, at 12-13, MGM Studios Inc. v. Grokster Ltd., 125 S. Ct. 2764 (2005) (No. 04-480) (noting the volume of material moving).
[145] *See* Brief of Computer Science Professors Harold Abelson et al., at 10, MGM Studios Inc. v. Grokster Ltd., 125 S. Ct. 2764 (2005) (No. 04-480); Brief of Creative Commons, at 11, MGM Studios Inc. v. Grokster Ltd., 125 S. Ct. 2764 (2005) (No. 04-480) (on sharing of capacity at the edges).
[146] DUNCAN J. WATTS, SIX DEGREES (2003) (identifying the superiority of multiscale, ultrarobust networks); *see generally* Cooper, *supra* note 52, at 117-26 (describing the structure of the Internet).
[147] *See* Brief of Sixty Intellectual Prop. & Tech. L. Professors et al., at 28, MGM Studios Inc. v. Grokster Ltd., 125 S. Ct. 2764 (2005) (No. 04-480).

carrying capacity of current peer-to-peer networks exists precisely because those networks are decentralized.[148] The value of decentralized communicating nodes is realized when the nodes directly communicate with one another as they allow peer-to-peer networks to be efficient, robust, and scalable.[149] This open architecture allows for efficient solutions when there are scarce resources by exploiting resources that are more abundant.[150] Peer-to-peer network spread the distribution costs among millions of computers giving "content owners far more flexibility in making their works available to the public" and spawning "new business applications that utilize distributed computing technology."[151]

While open source software is the collaboration of a few highly skilled individuals working together, peer-to-peer networks represent a broader phenomenon. They draw in both technical and non-technical participants because of the widespread deployment of devices and software capable of simple deployment of peer-to-peer networks allowing non-technical people an easy way to join peer-to-peer networks.[152] As with open source software, people must be willing to participate, but the level of engagement is much more variable and potentially lower in peer-to-peer networks. However, the level of engagement varies. On the passive end of engagement are peer-to-peer file sharing networks. These networks only require that participants put up and take down files. At the other extreme, very active collaboration is possible. Wikis require that participants co-produce a document by sequentially editing and or commenting on an emerging product.[153]

B. Transaction Cost Reductions

1. Open Mesh Networks

As technology advances, smart technologies will allow for more transmissions in open mesh network due to changes in the frequency, timing, and spacing of transmissions.[154] Due to the way the network is organized, when transmitters leave the network, the work they were doing can be taken over by other transmitters regardless of whether the transmitters are repeaters or not.[155] Seamlessness is essentially already built into devices, as it is a matter of technical protocol.[156] As carrying capacity is developed, the full set of physical transactions must take place in all cases for the open mesh networks to become dynamic environments. The embedding of coordination protocols in a commons approach avoids the costs and challenges of negotiating, clearing, billing, and enforcing rights that will make transactions more costly.[157]

A traditional analysis of such a common-pool resource would focus on the allocation costs, external benefits of different rules, and transaction costs. However, as open mesh networks are non-depletable, the only relevant allocation cost is the congestion cost. Unlike traditional common-pool resources, when dealing with open mesh networks, any rules urging a restriction of capacity should be suspect and any promoting increases in capacity should be preferred. As discussed above, because open mesh networks are dynamic,

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[148] *See* Albelson, *supra* note 145; Brief of Creative Commons, *supra* note 145.
[149] *See* Albelson, *supra* note 145, at 10-11.
[150] *See* Creative Commons, *supra* note 145.
[151] Brief of Distributed Computing Indus. Ass'n, at 15, MGM Studios Inc. v. Grokster Ltd., 125 S. Ct. 2764 (2005) (No. 04-480).
[152] LEE RAINEE & MARY MADDEN, THE STATE OF MUSIC DOWNLOADING AND FILE SHARING ONLINE, PEW INTERNET AND AMERICAN LIFE PROJECT 2 (2004) (estimating 34 million KaZaa Media Desktop File Sharing Applications actively running in June of 2003); Lerner & Tirole, *supra* note 142, at 204 (estimating, "Computer system administrators, database administrations, computer programmer, and other computer scientists and engineers represent about 2.1 million jobs in the united states.").
[153] However, it is interesting to note that it is the activities that require little participation that are getting the most attention, especially as far as legal attention such as with file sharing.
[154] Arnon Tonmukayal & Martin B.H. Weiss, *An Agent-Based Model for Secondary Use of Radio Spectrum*, IEEE Int'l Symp. on New Frontiers in Dynamic Spectrum Access Networks (Nov. 8-11, 2005).
[155] Brown, *supra* note 136.
[156] J. Giacomoni & D.C. Sicker, *Difficulties in Providing Certification and Assurance for Software Defined Radios,* IEEE Int'l Symp. on New Frontiers in Dynamic Spectrum Access Networks (Nov. 8-11, 2005).
[157] Berger, *supra* note 128, at 4.

the transaction costs associated with negotiating clearance rights to transmit are high.[158] This challenge will become even greater as more transmitters and receivers become mobile. Solving the transaction problem at the physical level and avoiding haggling is over rights is the most attractive solution.[159]

2. Open Source

At the institutional level of open source projects, there is a large base of contributors because entry into open source development is easy, free, and casual,[160] which allows open source participants to tackle complex and diverse projects.[161] Many of the programmers of open source are also the users of the products. At the individual level, there are a large number of motivations for participating in open source development[162] and open source projects allow for self-selection of tasks.

Two aspects of open source help reduce transaction costs. First, the demand-side advantage to open source is that programmers are also consumers.[163] This increases the value of the product and the "willingness to pay" in a non-commodified sense of contributing time and effort to the collaborative.[164] Second, the agency costs of separating users from producers discussed in the case of open source are, of course, transaction costs.[165] In open source, the technical skills of the programmer community play an important role.[166] von Hippel underscores the potentially revolutionary development that flows from the transformation of users into producers because users can "build, consume, and support innovations on their own, independent of manufacturer incentives" and allows for a "diffusion of innovation by and for users… to get what they really want."[167]

3. Peer-to-Peer Networks

When looking at the transaction cost advantages of peer-to-peer networks, the production and distribution of music continue to be the focal point.[168] The costs involved with searching for music decreases and the information quality received improves.[169] This, in turn, reduces the total costs and increases demand for music.[170] In addition, especially important for the artists, peer-to-peer networks change how music is produced and distributed[171]

Distribution of recorded music over the Internet decreases the costs of producing, manufacturing, and distributing music because there is no longer a cumbersome centralized distribution system.[172] Peer-

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[158] Benkler, *supra* note 74.
[159] N. Ikeda, *The Spectrum as Commons: Digital Wireless Technologies and the Radio Policy*, Research Institute of Economy, Trade and Industry, at 10 (2002).
[160] Lerner & Tirole, *supra* note 142 (noting the dramatic increase in participation in open source projects in the 1990s); WEBER, *supra* note 5, at 65-72 (describing the wide range of participation in projects).
[161] WEBER, *supra* note 5, at 59-65 (discussing "distributed" work).
[162] Karim R. Lakhani & Robert G. Wolf, *Why Hackers Do What They Do: Understanding Motivation and Effort in Free/Open source Software Projects*, *in* PERSPECTIVES ON FREE AND OPEN SOURCE SOFTWARE, *supra* note 95; Rishab Aiyer Ghosh, *Understanding Free Software Developers: Findings from the FLOSS study*, *in* PERSPECTIVES ON FREE AND OPEN SOURCE SOFTWARE, *supra* note 95.
[163] VON HIPPEL, *supra* note 95.
[164] WEBER, *supra* note 5, at 74 (emphasizing the importance to programs of participation to solve a problem that concerns them in the suggestion that programmers "scratch and itch.").
[165] VON HIPPEL, *supra* note 95, at 276.
[166] *Id.*
[167] *Id.*
[168] WILLIAM W. FISHER, III, PROMISES TO KEEP 18-31 (2004).
[169] Brendan M. Cunningham, Peter Alexander & Nodir Adilov, *Peer-to-Peer Sharing Communities,* INFORMATION ECONOMICS AND POLICY, 16 (2004).
[170] FISHER, *supra* note 168, at Appendix.
[171] *See* Mark N.Cooper, *Time for the Recording Industry to Fact the Music: The Political, Social and Economic Benefits of Peer-to-Peer Communications Networks* (2005), *available at* http://cyberlaw.stanford.edu/blogs/cooper/archives/BENEFITSofPEERtoPEER.pdf.
[172] FISHER, *supra* note 168, 260, app. tbl.A.1 (2004); DERECK SLATER ET AL., BERKMAN CTR. FOR INTERNET AND SOC'Y, HARVARD LAW SCHOOL, CONTENT AND CONTROL: ASSESSING THE IMPACT OF POLICY CHOICE ON POTENTIAL ONLINE BUSINESS MODELS IN THE MUSIC

to-peer networks further reduce costs by lowering record company overhead and marketing, which currently account for approximately a quarter of the cost of music.[173] This eliminates up to three-quarters of the costs; one author notes that while the average price per CD in 2001 was about $17.99, the production cost was about fifty cents and the artists only received about twelve cents.[174] While some say artists receive more, even those authors do not place the amount much higher than a dollar, net of costs.[175] Thus, the costs of music decrease dramatically by reducing, or even eliminating, the role of intermediaries. Distribution of music over peer-to-peer networks allows this decrease as producers of goods and services find new ways to deal directly with consumers. In addition, consumers also are able to establish relations with one another, or to become producers in their own right

C. The Demand-Side Value Enhancement

1. Open Mesh Networks

Although the benefit of open wireless networks lies primarily on the supply-side, there are benefits to the demand-side. In order to capture the full benefits of a spectrum commons, people must form ad hoc mesh networks.[176] To appreciate this, we must understand the devices used in and the creation of ad hoc mesh networks (see Exhibit 6).[177]

Devices used for open wireless networks will need to detect use of the spectrum, assess the quality of service it needs for its own transmission, and ascertain whether transmitting in the space available and in the necessary manner can be done without interfering with other devices.[178] These devices become cognitive as they "identify, remember, update, share opportunity information, and exploit the opportunity information with adapted transmission to avoid causing harmful interference."[179] Exhibit 6 illustrates this concept starting on the bottom left and working to the top right: each of the concepts subsumes construction of the one below as a complex network.

To make a cognitive device, one starts with the basic building block of the network: a device that uses software, as opposed to hardware, to change its frequencies, power, and modulation.[180] When one adds sensors and a reasoning system to the device, the device becomes cognitive and aware of the rules of the network.[181] Embedded logic systems allow them to decide when to transmit without breaking the law adding intelligence to the network.[182] Mesh wireless networks then integrate these devices as access points and relay nodes (repeaters) used to support any communication meant for any destination.[183]

The group forming value emerges as ad hoc network allow radios to join and leave the network. Therefore, they adapt as necessary, since the "connections are transient and formed in an ad hoc as-needed basis" allowing for the development of a "self-healing networking in which routing continues in the face of broken nodes or connections."[184] Unlike the networks that existed in the spectrum during the twentieth

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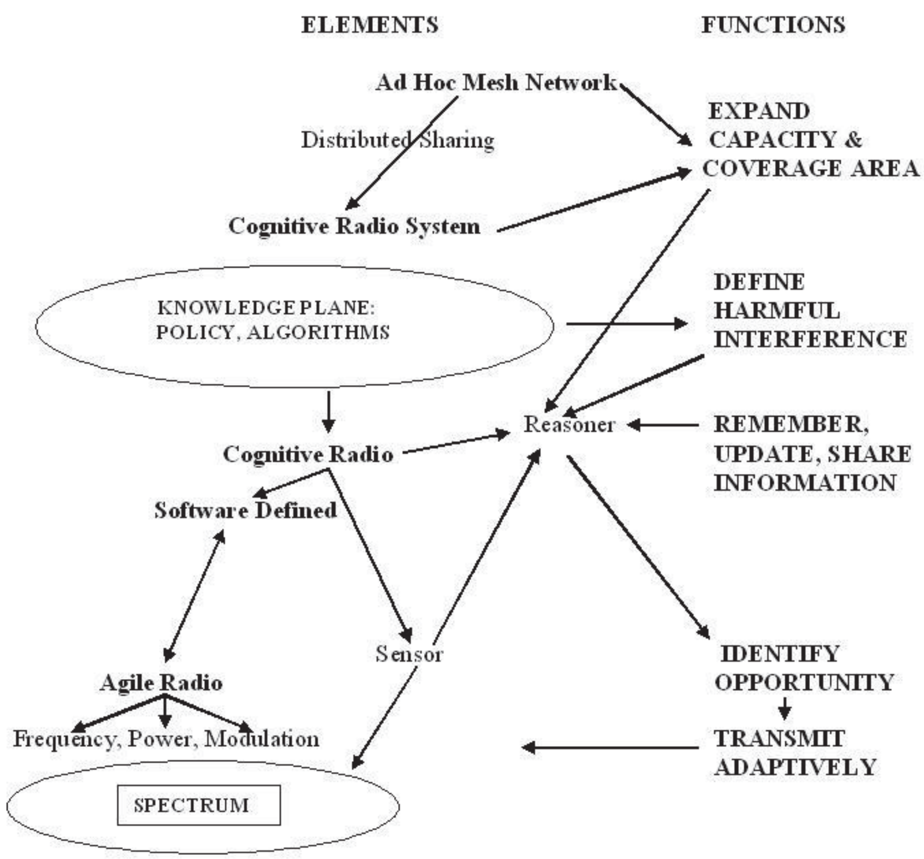
AND FILM INDUSTRIES AV-I (2005), *available at* http://cyber.law.harvard.edu/media/files/content_control.pdf.
[173] *Id.*
[174] Bill Wittur, *Selling Minor Chords in Exchange for a Happy Tune*, MUSIC DISH, (Dec. 12, 2004) *available at* http://musicdish.com/mag/index.php3?id=4859.
[175] FISHER, *supra* note 168, at 260, app. tbl.A.1.
[176] Giacomoni, *supra* note 156.
[177] Berleman et al., *supra* note 131.
[178] *Id.* at 4.
[179] Robert J. Degroot et al., *A Cognitive-Enabled Experimental System*, IEEE Int'l Symp. on New Frontiers in Dynamic Spectrum Access Networks (Nov. 8-11, 2005).
[180] Berleman et al., *supra* note 131.
[181] *Id.*
[182] *Id.*
[183] *Id.* at 4-8.
[184] Giacomoni, *supra* note 156.

century, cognitive devices in ad hoc networks show the ability of human intelligence to build incredibly complex, replicable networks that embed coordination. At the core of the network is the reasoner – "a software process that uses a logical system to infer formal conclusions from logical assertions."[185] It works by "inferring statements from other statements… represented in a machine understandable way… that allows not only first-order logics, but also higher-order, class-based reasoning."[186]

Exhibit 6: Mesh Network Elements and Functions



2. Open Source

The demand-side values are enhanced with open source because at the core of its success is peer-review at both the institutional and individual levels. Individually, peer review among programmers promotes professional development and motivates participation.[187] Institutionally, peer review promotes quality by vetting output across a large audience. The reliance on open communication through mail lists, websites, Wikis, and collaborative tools helps create an environment inductive to peer review.[188]

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[185] Berleman et al., *supra* note 131.
[186] *Id.*
[187] FELLER & FITZGERALD, *supra* note 143, at 88.
[188] WEBER, *supra* note 5, at 81 (putting it simply, "Talk a lot.").

In addition, there is a clear set of group values and norms used to evaluate programs. Standardization and reuse are important.[189] Communication is important among all members of the community shown by project administrators making frequent releases and builds of programs available.[190] Social commitment – a broad category that includes altruism – and ideological motives, such as personal motivation to do a good job or a dislike of proprietary code, also come into play.[191]

3. Peer-to-Peer

The demand-side of peer-to-peer networks encourages three different forms of relationships between individuals: exchange, viral communications, and collaboration.[192] Peer-to-peer networks foster exchange between equals by the search capability of the network and the direct relationships between nodes. As the capacity for networks to communicate increases, peer-to-peer networks exhibit classic demand-side economies of scale. Viral communications and collaboration enhance the ability to market and expand the ability to innovate as shown with the new emerging relationship between artists and fans.[193] In addition, peer-to-peer collaboration can be anonymous, where individuals sequentially add to or modify a product,[194] and they can be interactive co-production.[195]

The demand-side is also changed because the relationship between artists and audiences changes. The hold of the recording companies weakens and their ability to make stars decreases, as "there is a greater probability of discovering other high quality music items by lesser known artists with the new technology."[196] The ability to sample "is an information-pull technology, a substitute to marketing and promotion, an information-push technology."[197] The cost structure of the industry changes as it adopts digital technologies. Performance improves, as "variable costs relative to fixed costs are more important for music downloads than for CDs."[198] The ability for lesser-known artists to succeed increases due to "a less skewed distribution of sales among artists."[199] In fact, we do observe this pattern. The payoff for artists and society is increasing diversity.[200] In addition, it creates the opportunity for the artists to gain more from "piracy" than the publishers as illegal recordings may create a larger demand for live performances as an artist's popularity increases.[201]

CONCLUSION

There is a twilight zone in economics between market failure and market success inhabited by public goods and externalities. Collaborative production, and the goods it creates, will play a key role in filling this zone and creating economic growth in the digital age. The location of these goods with respect to traditional economic analysis is clear. In the industrial economy of the 20th century, economic analysis grappled with goods that were non-rivalrous and non-excludable.[202] However, in the digital economy of the 21st century, computer and communications technologies expand the challenge of economic analysis.

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[189] *Id.* at 75.
[190] *Id.* at 80.
[191] Lakhani & Wolf, *supra* note 162.
[192] Brief of Sovereign Artists, at 6-7, MGM Studios Inc. v. Grokster Ltd., 125 S. Ct. 2764 (2005) (No. 04-480).
[193] *See* Brief of Distributed Computing Indus. Ass'n, *supra* note 151, at 19.
[194] Brief of Sovereign Artists, *supra* note 192.
[195] *Id.* at 38.
[196] Ram. D. Gopal et al., *Do Artists Benefit from Online Music Sharing?*, 79 J. OF BUS. 1503, 1530 (2006).
[197] MARTIN PEITZ & PATRICK WAELBROCK, FILE-SHARING, SAMPLING, AND MUSIC DISTRIBUTION 5 (Int'l U. in Germany, Working Paper No. 26, 2004), *available at* http://ssrn.com/abstract=652743.
[198] Martin Peitz & Patrick Waelbroeck, An Economist's Guide to Digital Music 35 (CESifo Working Paper No. 1333, 2004), *available at* http://ideas.repec.org/p/ces/ceswps/_1333.html.
[199] *Id.*
[200] Gopal et al., *supra* note 196, at 1525-29.
[201] Amit Gayer & Oz Shy, *Publishers Artists and Corporate Enforcement,* INFO. ECON. & POL'Y (forthcoming 2006) (manuscript at 2-3, on file with author).
[202] TAYLOR, *supra* note 32; *see generally,* OSTROM, *supra* note 45.

Anti-rivalry and inclusiveness are critical economic conditions. The value of anti-rival and inclusive goods increases as more users participate freely in their production, consumption, and distribution.[203] By failing to implement policies that allow collaborative production to thrive in group-forming networks, society will suffer greatly.

To avoid this pitfall, it is necessary to understand the broad policy implications of choosing a mode of production. Developing specific policies in a number of areas will promote the efficient expansion of collaborative production. Broad policy goals must be developed with a clear understanding of what implications these goals will have for the telecommunication world.

A. Broad Policy Goals

Several characteristics of the collaborative mode of production give policymakers reasons to support it, including five economic and socio-political characteristics. First, there is accommodating uncertainty. Decentralized user driven focus has clear advantages in flexibility.[204] It is less dependent on small numbers of network owners guessing what the demands on the network will be. It avoids large lumpy investment. It helps to lower the cost of updating and versioning. Flexibility enhances the ability of the structure to accommodate uncertainty.

Second, there is innovation. The decentralized end-user driven innovation is likely to accommodate far more experimentation and innovation.[205] As I have shown, the experience of unlicensed spectrum in the age of digital technology shows that networked platforms exhibit the fundamental characteristic of user-driven innovation and aggressive atomistic competition because of its decentralized nature.

Third, there are incentives and infrastructure. Centralized networks give network operators an incentive and ability to exercise market power, to reduce or control communications to maximize private profits.[206] The social cost of the exercise of market power in communications networks grows because it retards the ability to achieve collaborative gains.[207] In collaborative production systems with embedded coordination, decentralized investment, and cooperation gain, this ability to abuse market power is reduced.[208]

Fourth, there is the democracy principle. Although this paper has focused on economic issues, there is no doubt that decentralized open networks have desirable political characteristics.[209] The licensing regime that protected broadcasters excluded people from projecting their voices, thus limiting their right to speak.[210] Because of the one-way broadcast nature of twentieth century electronic mass media, the First Amendment concentrated on the ability to hear diverse points of view, also known as listeners' rights.[211] Open wireless and peer-to-peer networks expand the ability to speak and help ensure First Amendment rights by returning them more closely to their original formulation.[212]

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[203] *See* Section II, *supra*.
[204] W. Lehr, *The Economic Case for Dedicated Unlicensed Spectrum Below 3 GHz*, 8 (2004), *available at* http://itc.mit.edu/itel/docs/2004/wlehr_unlicensed_doc.pdf.
[205] *Id.*
[206] Reed, *supra* note 67.
[207] Lehr, *supra* note 204, at 16-23.
[208] Lehr, *supra* note 204 (arguing unlicensed spectrum provides a check on market power).
[209] *See* Yochai Benkler, *Free as the Air to Common Use: First Amendment Constraints on Enclosure of the Public Domain*, 74 N.Y.U. L. REV. 354 (1999); Yochai Benkler, *Property Commons and the First Amendment: Toward a Core Common Infrastructure* (White paper for the Brennan Center for Justice) (2001), *available at* http://www.benkler.org/WhitePaper.pdf.
[210] Mark Cooper, Spectrum and Speech in the 21st Century (2006), *transcript available at* http://cyberlaw.stanford.edu/blogs/cooper/archives/spectrum%20is%20speech.pdf.
[211] *Id.*
[212] LAWRENCE LESSIG, CODE AND OTHER LAWS OF CYBERSPACE (1999).

Fifth, there is the idea of creativity. There is a socio-cultural benefit in the growth of collaborative production independent of the aspect of political expression.[213] The pleasure in creativity, attributed to the open source coder, is simply an example of the broader principle that self-expression through creative production is satisfying. Similarly, the desire to contribute without compensation is strong. People want to participate in the production of culture.

B. Communications Policy

This analysis has broad implications for many areas of public policy (see Exhibit 7). The key principle of expanding the flow of information from the ends of the network, the end-to-end principle, is the cornerstone of the value creation. The unimpeded flow of communications is the key to collaboration on the supply-side and group formation on the demand-side. Future allocative and adaptive efficiency will depend upon a pervasive computing environment in which the endpoints are mobile.

Open wireless networks in the spectrum commons are better able to support such activity. Massive mobile computing is the future; the Sarnoff broadcasting networks are the past. A progressively expanding swath of unlicensed spectrum should be the main policy. Unlicensed spectrum is not the exception; it should be the rule. If unlicensed space becomes congested, it is necessary to move licensed applications out of the way, especially in the lower frequencies.

Exhibit 7:

PRESERVE EXISTING USER RIGHTS

Preserve nondiscriminatory Interconnection and carriage (network neutrality) in communications networks

Protect fair use and fight to preserve routine, unregulated uses.

REFORM THE CURRENT SYSTEMS OF PROPERTY RIGHTS

Include broadband connectivity in the definition of universal service

Defend and expand community broadband

Liberate orphaned and dormant (out of print) works

Reduce the burden of search costs to discover existing rights

PREVENT EXTENSION OF RIGHTS THAT IMPAIR COLLABORATION

Oppose discrimination in communications networks

Resist copyright holders defining communications architecture to protect their rights

Refuse to create new transmission privileges (e.g. the webcaster treaty)

Oppose technology mandates that undermine functionality (e.g. the broadcast flag)

Oppose excessive enforcement measures (e.g. criminalization or expansion of secondary or vicarious liability

Network neutrality is vital to supporting the economics of collaboration. Tollgates and barriers restrict the flow of information and the ability of groups to form. Policymakers must resist the efforts of incumbents to throttle down the flow of information in the digital communications platform. As long as wire owners have leverage over last mile, middle mile, or backbone facilities, they cannot be allowed to

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[213] *See* Brief of Creative Commons, *supra* note 145.

undermine innovation in applications and content by withholding network functionality or discriminating against content or applications. Ironically, the torrent has barely begun and the oligopoly network owners are already complaining about bandwidth hogs consuming too much capacity, which will set off a campaign to restrict communications by price, or profit maximizing discrimination. Differentiation that utilizes enhanced network functionality is fine; discrimination that denies access to network functionalities is not. Open interfaces that promote seamless communications must remain the organizing principle of the network. The unfettered, many-to-many quality of the network must be preserved.

Telecommunications is infrastructure in the digital information age. More than ever, a ubiquitous and adequate communications network that is available, accessible, and affordable for all should be the objective of public policy. Because communications are so central to this economy, it is absurd not to have an industrial policy to ensure the achievement of this public policy. Universal service is more important in the 21st century than it was in the 20th because it creates a large market. In this network the sources of efficiency and innovation are dispersed and, frequently, accidental or surprising. The next big thing is not likely to come from the research and development departments of the incumbents.

There is a wide range of intellectual property issues that swirl around collaborative production, too many to address in this paper. From the point of view of information flow and communications, content owners should not dictate network architecture. If Hollywood and the music companies have their way, they will tag every file, fingerprint every user, and monitor every transaction. They will do so by forcing transactions back through a central server, which undermines the efficiency of exploiting distributive resources in peer-to-peer networks.