THE ECONOMICS OF COLLABORATIVE PRODUCTION:

A FRAMEWORK FOR ANALYZING THE EMERGING MODE OF DIGITAL PRODUCTION

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I. INTRODUCTION

A. REALITY CHALLENGES THE OLD PARADIGM

This paper argues that the dramatic growth of collaborative activities constitutes the emergence of a new mode of information production based on superior economics of collaborative production in the presence of digital computer/communications platforms. This new mode of production challenges fundamental concepts of the role and function of property and commercial relationships in the production of information goods.

The paper develops definitions to describe the economic and institutional success of collaborative production by extending the concepts of public goods and common pool resources. While public goods and common pool resources exhibit traits of non-rivalry and non-excludability, collaborative goods exhibit characteristics of anti-rivalry and inclusiveness. These traits are found, to various extents, in each of the areas discussed in the paper – WiFi, which uses unlicensed or open spectrum, the open source software movement, which relies on non-property relations and peer-to-peer networks, which rely on non-commodified exchange.

It is risky to use concepts like commons and non-commodified relations to describe a superior form of economic organization for early-21st century America. It runs into the teeth of the dominant analytic paradigm, which relies on neoclassical economics to press for the strengthening and extension of exclusive property rights—the antithesis of a commons—in all aspects of economic life. Yet, the interest in these phenomena is driven by empirical facts that are impossible to disregard, and risky in their own right to ignore.

The cover story from the August 2005 issue of Wired magazine opined that shared, collaborative production is the near future’s “main event.” In marking the 10th anniversary of the initial public offering of Netscape, a landmark in the growth of the World Wide Web, Wired sees a revolution that penetrates to the core of daily life with the transformation of consumers into producers.¹

At its heart was a new kind of participation that has since developed into an emerging culture based on sharing. And the ways of participating unleashed by hyperlinks are creating a new type of thinking – part human and part machine – found nowhere else on the planet or in history…

What we all failed to see was how much of the new world would be manufactured by users, not corporate interests…

Linking unleashes involvement and interactivity at levels once thought unfashionable or impossible. It transforms reading into navigating and enlarges small actions into powerful forces.
The electricity of participation nudges 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. More and more of the Web runs in this mode. One study found that only 40 percent of the Web is commercial. The rest runs on duty or passion.

Coming out of the industrial age, when mass-produced goods outclassed anything you could make yourself, this sudden tilt toward consumer involvement is a complete Lazarus move… The deep enthusiasm for making things, for interacting more deeply than just choosing options, is the great force not reckoned 10 years ago. The impulse for participation has upended the economy and is steadily turning the sphere of social networking – smart mobs, hive minds, and collaborative action – into the main event.²

A month after Wired celebrated the explosion of collaborative production, Business Week ran a similar story under the headline: “It’s A Whole New Web.”³

Over that same 10-year period the commons approach to spectrum management – the elimination of exclusive rights to parts of the spectrum – has had an equally impressive run. The remarkable success of WiFi was achieved by allowing open access to parts of the spectrum that were allowed to go unlicensed because they were considered to be “junk” or “garbage.”

Some of the bands of spectrum originally designed for unlicensed uses (such as garage door openers) were widely regarded as “garbage bands.” As for the band of frequencies around 2.4 gigahertz (GHz), for example, many industry observers concluded that the assorted unlicensed uses – mostly industrial, non-commercial uses like microwave ovens – crowded the spectrum sufficiently such that no reliable service could operate in that range. Undeterred by the crowded nature of the spectrum, the Institute of Electrical and Electronic Engineers (IEEE) developed a standard for wireless broadband that would operate in the 2.4 GHz band of spectrum. The subsequent success of the 802.11 standard, popularly known as Wi-Fi-related devices, has demonstrated that unlicensed spectrum can be big business. In 2003 alone, for example, equipment manufacturers sold more than $2.5 billion in Wi-Fi-related devices. For 2004 it was estimated that public Wi-Fi hot spots would reach “almost 1400 worldwide with some 30 million users.” To top it off, former FCC chairman Powell and others have touted wireless broadband using unlicensed spectrum as a financially viable approach for delivering broadband services to rural areas. Not bad for a garbage band.⁴

Wi-Fi is a very technical area, where algorithms and protocols drive collaborative production. If the change in production had been limited only to this type of activity, it would not have such a dramatic impact. However, the change extends to what I call people-to-people networks, where technology plays a part but the social organization itself is equally, if not more responsible for the endgame. Here, Wikis are the quintessential example.
Wales set out to build a massive online encyclopedia ambitious in purpose and unique in design. This encyclopedia would be freely available to anyone. And it would be created not by paid experts and editors, but by whoever wanted to contribute. With software called Wiki – which allowed anybody with web access to go to a site and edit, delete or add to what’s there – Wales and his volunteer crew would construct a repository of knowledge to rival the ancient library of Alexandria.

In 2001, the idea seemed preposterous. In 2005, the nonprofit venture is the largest encyclopedia on the planet. Wikipedia offers 500,000 articles in English – compared to Britannica’s 80,000 and Encarta’s 45,000 – fashioned by more than 16,000 contributors. Tack on editions in 75 other languages, including Esperanto and Kurdish, and the total Wikipedia article count tops 1.3 million.

In the beginning, encyclopedias relied on the One Smart Guy Model.

With the Industrial Revolution, the One Smart Guy approach gradually gave way to the One Best Way model, which borrowed the principles of scientific management and the lessons of assembly lines.

Now Wales has brought forth a third model – call it One for All. Instead of one really smart guy, Wikipedia draws on thousands of fairly smart guys and gals – because in the metamathematics of encyclopedias, 500 [fairly smart people] equals one Pliny the Elder. Instead of clearly delineated lines of authority, Wikipedia depends on radical decentralization and self-organization – open source in its purest form. Most encyclopedias start to fossilize the moment they are printed on a page. But add Wiki software and some helping hands and you get something that is self-repairing and almost alive. A different production model creates a product that’s fluid, fast, fixable, and free.

“Reality has a way of forcing debates.” This dramatic success poses a challenge, not only to the dominant economic paradigm, but to a broad range of received social science thinking. Traditional economic analysis hypothesized that large producers would reap the benefits of network externalities, also known as demand side economies of scale, by tracking usage and targeting users with a form of cyberspace direct mail on steroids in which instant point and click gratification delivered sales of large, bundled packages. Sociologists feared an acceleration of isolation in the Bowling Alone syndrome, as the focal point of interaction shifted from the face-to-face physical world to anonymous, fleeting interactions in cyberspace. Political scientists, applying the Logic of Collective Action, expected collaborative processes to break down under the weight of free riders.

There is mounting evidence, though, 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.
The ever-declining costs of digital production and distribution have thwarted the predicted dominance of large bundles of information goods. Increasing returns have instead been realized by large numbers of producers 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.

Rampant couch potatoism has recently been replaced with an explosion of online participation because the passivity of the 20th century was bred by the uniquely one-way nature of the dominant broadcast media—it was not endemic to viewers. When offered the opportunity to participate and communicate in the digital information age, people quickly accept. The potential for collective action was far greater than anticipated. Group formation has been widespread as a result of 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.

Responding to this challenge requires that the analysis be directed towards ultimately providing a means of assessing the social optimality properties of the way “open science,” “open source,” and kindred cooperative communities organize production and regulate the quality of the information tools and goods – outputs that will be used not only for their own, internal purposes, but also by others with quite different purposes in society at large.

B. Approach and Outline

The paper focuses on the unique moment created by the emergence of digital technologies and identifies the fundamental conditions created for the production of information goods, seeking to extract common threads across these areas offering a “systematic investigation in view of a particular conjuncture”

Information-goods that share these technical properties are moving increasingly to the center of the stage as drivers of economic growth… The enabling of peer-to-peer organizations for information distribution and utilization is an increasingly obtrusive consequence of the direction in which digital technologies are advancing… The “open” (and cooperative) modes of organizing the generation of new knowledge have long been recognized to have efficiency properties that are much superior to institutional solutions to the public goods problems, which entail the restriction of access to information through secrecy or property rights enforcement.

The profound impact of the revolution in the production of information is underscored by the notion that we live in an information economy, for it pulls in the broad categories of intellectual property and communications facilities. The definition of intellectual property offered by Landes and Posner provides the link.

By “intellectual property” we mean 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.18

In these terms, the logic of collaborative production requires that we re-examine and adjust the existing economic rationale for bringing information under a legal regime of property rights” and modify that regime to promote the expansion of collaborative production of information gods.

To make the case, I start by locating communications/information products in the traditional framework of market structure, arguing that they are generally not simple private goods. Spectrum is a common pool resource, while communications facilities are infrastructural, public goods. Ideas, qua information goods, have long been a challenge for traditional economic analysis and policy.

Locating the communications/information issue in this framework serves two purposes. First, it is grounded in historical experience. Second placing the issue of communications/information property and regulation at the intersection of infrastructure, public goods and externalities provides a familiar analytic framework for dealing with the changes that are taking place in this sector. The transformation we are observing is not alien, but fits within a theoretical and experiential framework that is familiar. It simply requires expanding the concepts to incorporate new conditions.

I take a structural view of industrial organization19 and an institutional view of economics,20 in which transaction costs play a key role.

Structural economics teaches that when basic economic conditions change as dramatically as they have in the past couple of decades, we should not be surprised to find fundamental changes in economic structure, conduct and performance. There has been a revolutionary change in technology on the supply-side and a shift in the way goods are marketed on the demand side that affects transaction costs.

Institutional economics focuses on cooperation and transaction costs as a challenge to economic systems.21 Institutional analysis argues that in addition to the costs of production – the transformation costs in the economy – transactions are a central part of the total cost in the economy. Indeed, transaction costs are of equal, if not greater, importance than the transformation costs of production processes, especially as the economy becomes more focused on services. As Douglass North has written:

There is a different, and I think, better story. It concerns the endless struggle of human beings to solve the problems of cooperation so that they may reap the advantages not only of technology, but also of all the other facets of human endeavor that constitute civilization…

Institutions provide the basic structure by which human beings throughout history have created order and attempted to reduce uncertainty in exchange. Together with the technology employed, they determine the transaction and transformation costs and hence the profitability and feasibility of engaging in economic activity…
In examining stability and change in history, the initial issue is... What combination of institutions permits capturing the gains from trade inherent in the standard neoclassical (zero transaction cost) model at any moment of time?²²

From the point of view of industrial organization, the need to create a new category of goods reflects a very fundamental shift in the means of production. From the point of view of institutional economics, the importance of new institutional relations must reflect a fundamental shift in transaction costs as well as in the flow of technology and knowledge. The underpinning of the argument in this paper that collaborative economics is a superior form of industrial organization rests on the intersection of changes in the technologies of transformation, transaction, and knowledge.
II. ANALYTIC FRAMEWORK

A. Traditional Goods

1) Characteristics of Traditional Goods

Economic analysis has long recognized that under certain conditions competitive markets do not produce socially desirable outcomes. 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 value that best serve society.

We consider two kinds of markets that are not likely to allocate resources efficiently, even though they might otherwise be competitive: markets with externalities and markets with public goods… An externality arises when the action of any consumer or producer affects the costs or benefits for other consumers or producers in some way not transmitted by market prices.

A public good is a good that benefits all consumers, even though individuals may not pay for the costs of production….

Why worry about externalities and public goods? The short answer is that, in a competitive market, the invisible hand may not guide the market to an economically efficient amount of production when there are externalities or public goods.23

These market failures occur where goods lack the critical characteristics that make private property based transactions easy (see Exhibit 1A). 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.”24 A private good is rival since “consumption by one person reduces the quantity that can be consumed by another person”25 and exclusive since “consumers may be denied access.”26

The central claim for the superiority of private goods is that where resources are rival or subtractable, efficiency requires they be devoted to their highest valued use. Exclusion gives the owner of the resource the incentive to husband the resource, especially where investment is necessary to replenish it. Market allocation solves the subtractability problem by directing resources to their highest value uses. The classic “tragedy of the commons” is the case where the failure to grant rights of exclusion leads to underinvestment in the resource and/or overuse.

When the rivalry and excludability conditions are absent, the provision of goods in markets become problematic. These characteristics lead to difficulties in production by private firms. Nonrivalry occurs where increased consumption of the good by one person does not decrease the amount available for consumption by others. Allocating these resources does no good, since they are not consumed in the traditional sense. Nonexcludability occurs where consumers cannot be excluded from consuming a good. The incentive to invest is undermined, since compensation cannot be extracted from “free riders.”
Exhibit 1: Types Of Goods

A. STANDARD DEFINITIONS

EXCLUSION/EXCLUDABILITY

Difficult

Public Goods

Common Pool Resource

Toll Goods

Private goods

Easy

RIVALRY/SUBTRACTABILITY

Low

High

B. ADDING NEW DIMENSIONS

EXCLUSION/EXCLUDABILITY

Difficult

Public Goods

Common Pool Resource

Toll Goods

Private goods

Easy

RIVALRY/SUBTRACTABILITY

Low

High

Inclusive

Collaborative Good

Network Good

Private/Collective Good

Antirival
This gives rise to the familiar typology of goods shown in Exhibit 1A. Note that I present the two characteristics as continua, rather than a two-by-two table, to underscore the fact that there are no 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 or common pool resource.

A public good exhibits nonrivalry in consumption and nonexcludability. Where individuals cannot be excluded they may withhold support for the provision of public goods, seeking a free ride. Where the costs of exclusion are high the value of the good may be consumed by the cost. These problems prevent public goods from being provided, even though they are good for the public.

But other problems and issues in private provision have also been identified. Transactions may not take place for a variety of reasons including excessive transaction costs and the inclination to try to “hold-up” transactions, seeking a larger share of the rents. Thus, the “tragedy of the anti-commons” in the excessive fragmentation of property rights, which prevent transactions from taking place, has also been recognized. In this case, the institutional arrangement creates such huge transaction costs and problems, that the transactions cannot be executed.

Common pool resources and their associated governance rules have also received increasing attention. These are resources that are non-excludable but rival. The solution to the problem of subtractability of common-pool resources is not necessarily private property. “If exclusion costs are comparatively high, common ownership solutions may be preferable.” The possibility of co-existence of different governance regimes is particularly important for common-pool resources.

Many CPR institutions are mixtures of “private-like” and “public-like” institutions...

Ostrom, in reporting on the institutional-economic analysis of a number of long-enduring, self-organized, self-governed CPRs, finds that private property and communal property can exist side by side.

If private rights prevent socially desirable transactions from taking place, then shared rights may allow them to occur. This has come to be known as the “comedy of the commons.”

While the tragedy of the commons is real, there are many instances where institutions develop to protect against overexploitation...Forests, irrigation systems, fisheries, ground water basins, grazing lands, and the air we breath are all examples of common-pool resources (CPRs). Because no one has property rights or control over such a resource, users of CPRs are frequently assumed to be caught in an inescapable dilemma – overexploitation of the resource, or what is commonly known as the “tragedy of the commons.” Many well-documents examples of overexploitation exist. The users of commonly held resources have, however, in many instances overcome incentives to destroy the resources and have developed long-enduring institutions – rules-in-use that enable them to utilize these resources more effectively. Understanding the conditions under which users...
of CPRs successfully develop and maintain effective institutions is critical to facilitating improved resource policies.\textsuperscript{33}

2) Relevant Examples

The above quote identifies the types of resources that have traditionally been identified as common pool resources. WiFi is an example from communications/information.

Public goods have played a larger role in the communications space. For centuries, communications networks have been treated as infrastructural, public goods but the distinctively American approach to the provision of these projects was to blend private capital with public interest obligations. Privately built communications networks were deemed to be “affected with the public interest,” which first took the form of common carrier regulation and later took on price, quantity and entry regulation.

Infrastructure is typically defined as a large investment that affects many aspects of the economy and exhibits substantial economies of scale.\textsuperscript{34} 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 time horizon, it is difficult for private actors to realize an adequate return on such projects. The number of suppliers is likely to be limited, a natural monopoly, at best a duopoly and at worst a “no-opoly.”

As an empirical matter there are several clear linkages between communication infrastructure and public goods.

- First, infrastructure generates positive externalities by stimulating economic activity and public goods solve the problem of the inability to internalize externalities in private, market transactions.
- Second, as a practical matter, when infrastructure projects are first deployed and for a large part of their economic life, they tend to be uncongested and therefore non-rivalrous.\textsuperscript{35} This is particularly true in low-density areas and at low levels of income.
- Third, traditionally, we only worry about public goods when they are infrastructure (except for national defense). These are important projects that society needs but they are not likely to be provided by private parties in adequate quantity or on terms of access that sustain the level of activity that is desirable.
- Fourth, infrastructure industries have generally been networks, connecting people and places. They have always exhibited network effects, where the value of the network grows as more people are connected to it. Information infrastructures in the digital age exhibit very strong network effects and all the positive externalities that result from them.
- Finally, these information networks have generally been shielded from the market, with franchises, subsidies, special contracts or other special treatment.
“The public goods character of intellectual property is pronounced.” Information has long been recognized to possess these characteristics – to be non-excludable, non-rivalrous and the fount of massive externalities.

Thomas Jefferson’s famous observation on ideas, captures this well, and also sets the stage for the linkage to the challenges of intellectual property issues as a communications issues.

If nature has made any one thing less susceptible than all others of exclusive property, it is the action of the thinking power called an idea, which an individual may exclusively possess as he keeps it to himself; but the moment it is divulged, it forces itself into the possession of every one, and the receiver cannot dispossess himself of it. Its peculiar character, too, is that no one possesses the less, because every other possesses the whole of it. He, who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me. That ideas should freely spread from one to another over the globe, for the moral and mutual instruction of man, and improvement of his condition, seems to have been particularly and benevolently designed by nature, when she made them, like fire, expansible over all space, without lessening their density in any point, and like the air in which we breathe, move, and have our physical being, incapable of confinement or exclusive appropriation. Inventions then cannot in nature, be a subject of property.

B. COLLABORATIVE GOODS

It is certainly possible to analyze communications and information in this traditional framework. Information still has public goods characteristics, even more so given the declining costs of distribution and copying. Communications facilities still have characteristics of infrastructure. While conditions of natural monopoly may have been eroded, it is by no means clear that this sector will support a sufficient number of firms to render them vigorously competitive. I have made that case elsewhere, but that critique is insufficient to capture the fundamental change in the production of information goods and the communications that is taking place.

Under the current conditions of digital production and distribution, as well as the embedding of knowledge in computer and communications devices, the underlying economic concepts that have been used to define goods must be extended (see Exhibit 1B). The emergence of collaborative production of information goods on a wide scale suggests something more, different from common-pool resources and public goods. Rules governing common pool resources generally suggest a production process in which private appropriation of shared resources is accomplished. Public goods similarly represent a collective decision to provide an input for private consumption.

Collaborative production entails a direct relationship between producers on a continuous basis on non-market terms. This is joint production, not the collective supply of an input for private appropriation. I argue there are certain types of goods that exhibit anti-rivalry and inclusivity. These include goods where having others share and cooperate in the production/consumption of the good increases its value and the more people who use the good, the more valuable the good is.
In analyzing open source software, Steven Weber argues as follows.

The solution to this puzzle lies in pushing the concept of nonrivalness one step further... to positive network externalities. Call it a network good, or an antiviral good... The system as a whole positively benefits from free riders who will provide something of value to joint production... the more “free riders” in this setting, the better.39

This suggests an extension of the two traditional dimensions, but Weber equates the two characteristics of goods. I think they should be distinguished.

**Antirivalry** is a situation where sharing use/production of the good by one-person increases the amount/value of the good available to others. **Inclusiveness** is a situation in which the value or amount of a good available for use/production increases as the number of people using/producing the good increases. The latter characteristic is akin to a network effect, also known as demand side economies of scale, where 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. I would like to make a nuanced distinction between inclusiveness and a simple network effect here.

The benefits of network effects accrue to members of the network – directly or indirectly. The classic example of a direct network effect is a telephone whose value grows as the number of people who can be reached increases. The classic example of an indirect network effect is software, where an increase in the number of people using an operating system may increase the value of the system because more applications are developed for it. There is no direct connection between the members of the network. Still, the benefits accrue to the members of the network.

Frishmann argues for an additional distinction, an infrastructural or foundational effect.

Infrastructure effects resemble indirect network effects in the sense that a larger number or a wide variance of applications may lead to an increase in consumers’ valuation of the infrastructure or network. However, the externalities generated by public and social infrastructure are even more indirect. They are diffuse... not simply a function of increased availability of desired end-users or end-uses.40

Eric von Hippel’s work on user driven innovation and free revealing reinforces the distinction between anti-rivalry and inclusiveness I want to make. He identifies a private/collective good. This is a good for which individuals volunteer to support the supply of the good to the community of producers. This provides a nuanced difference from a common pool resource in that an independent private action produces the resource for the community. Private effort is freely revealed by innovators because they can

*inherently* obtain greater private benefits than free riders. These provide incentives for participation in collective action projects that need not be managed by project personnel. In summation: Innovations developed at private cost are often revealed freely, and this behavior makes economic sense for participants under commonly
encountered conditions… When the conditions are met, society appears to have the best of both worlds – new knowledge is created by private funding and then freely revealed to all.41

David Reed describes two characteristics of adaptive network architectures in the spectrum that parallel the concepts of antirivalry and inclusiveness. The characteristic Reed calls cooperation gain is the focal point of his analysis. This is the antirivalry principle identified earlier.

What is clear for analyzing networked architecture is that as the demand for capacity increases, and as the density of terminals increases, adaptive network architectures that involve cooperation among all of the communicating entities create radio systems whose capacity can scale as demand increases.

Compared to systems of dedicated, isolated links, networks provide much more transport capacity at much greater transport efficiency. This phenomenon, which I have begun to call cooperation gain, creates major economic benefits.42

Spectrum is a highly developed example analyzed in detail by Reed.

Property rights are a solution to the “tragedy of the commons” by allocating property to its most valuable uses. But property rights assume property is conserved. Yet, spectrum capacity increases with the number of users, and if proportional to N, each new user is self-supporting!43

The second characteristic Reed calls network optionality. It is a form of the inclusiveness principle identified earlier.

The system-wide option value of flexibility in a network scales proportionally to the square of the number of nodes, according to the law popularly known as Metcalfe’s Law. Similarly, the option value that accrues due to the ability to dynamically assign capacity depending on shifting demand can increase superlinearly as the number of cooperating nodes in a network. I call these network externalities network optionality.44

Benkler’s presentation of the sharing of spectrum points toward the gain from network optionality by stressing the value of expanding “the set of usable combinations.”

Property defines rights inefficiently. Dynamic utilization of computation, power and bandwidth adjusted every few nanoseconds is more efficient. Fixing chunks of one factor, subjecting them to transaction costs and strategic behavior, will lead to artificial limitations of the set of usable combinations. Property rights in bandwidth inefficiently fence a sub-optimal resource boundary.45
Exhibit 1B locates these characteristics of antirivalry and inclusiveness as extensions of the existing dimensions, but they could be placed in other areas. Thus, moving away from private goods in the rivalry dimension we move from high rivalry, which means that use by one subtracts from the use by another, to low rivalry, where it does not subtract, to the opposite effect — use by one adds to the potential for use by another. Moving away from private goods in the excludability dimension, we go from easy of keeping people out, to the difficulty of keeping people out, 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. As Risha Aiyer Ghosh has put it:

Information is not just an extreme nonrival good, in that many people can enjoy its benefits at the same time; information is also unusual in that ownership over it cannot be expressed through a public act of possession. You can possess information if you keep it to yourself – in which case it remains private, and nobody knows what it is that you possess. As soon as you make public the information you claim to own, it is public information that everyone can access since you no longer have natural control over it…. With information goods, your “property” can be secret and only possessed by you. However, if published – if distributed even to one other person – that information is no longer within your control.46

The difficulty of propertizing information does not guarantee collaboration, however. Collaborative production involves much more than weak private possession; it involves active joint production. The key is to recognize the large positive externalities associated with collaborative production. These increase value to the group through positive externalities and motivate individuals, who capture non-rivalrous benefits, to voluntarily participate. Free revealers 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 analytic problematic is radically different in the worlds of private and collaborative production. 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.
III. SOURCES OF ECONOMIC ADVANTAGE FOR COLLABORATIVE PRODUCTION IN THE DIGITAL AGE

A. TECHNOLOGICAL CONDITIONS

What are the conditions under which anti-rivalry and inclusiveness dominate? The critical factors are the availability of communications and information. All of these activities 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.

- Distributed computer capacity able to communicate at high speeds and low cost is the platform on which collaborative production is built.

Historically, dramatic changes in communications and transportation technology have affected society deeply, but 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. 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 new scope and efficiency for markets.

Because computing intelligence can be distributed widely, and the activities of the end-points communicated so quickly, interactivity is transformed. “As rapid advances in computation lower the physical capital cost of information production, and as the cost of communications decline, human capital becomes the salient economic good involved in information production.” Users become producers as their feedback rapidly influences the evolution of information products.

Recent analyses of technological innovation provide strong evidence that the digital communications platform transformed the very fabric of the innovation process – a process Ashish Arora, Andrea Fosfuri and Alfonso Gambardella call “the changing technology of technical change.” The technological revolution altered the information environment to make distributed solutions more feasible, fostering the uniquely user-focused character of the communications-intensive Internet solution.

von Hippel argues that “the primary irreversible factor that we speculate is making user-based design an increasingly attractive option is technological advance.” Technical change transfers the locus of control – “the recent evolution of technology and knowledge bases… has created greater opportunities for task portioning,” which allows greater local autonomy in decision-making. “Specifically, the main force behind the changing technology of technical change is the complementarity
between increased computational power and greater scientific and technological understanding of problems.”

The ability to embody knowledge in tools and software lowers the cost of transfer dramatically.54

- Open networks organized according to efficient principles that allow multi-scale connectivity are critical to the flow of information. These efficiency principles are exploited by and replicated in each of the sectors analyzed.

The fact that the technologies at the core of this revolution are platforms within networks reinforces the dynamic of change. “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.”55 They are important platforms because there are strong complementarities between the layers and each layer sustains broad economic activity in the layer above it.56

Communications and computer industries have always exhibited network effects and strong economies of scale.57 Digitization reinforces these economic characteristics because economies of scope reinforce economies of scale. The architecture of the network in which these technologies have become embedded 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.

Beyond the fact that they build on digital communications networks as a platform, there are other commonalities across these three areas.

Each of the areas of economic activity discussed in this paper has an advantage in resource generation and value creation. Each has

- Each has an advantage in transformation costs by bringing a higher level of cooperation into the production function that allows the sharing of critical resources (factors of production) lowers production costs.

- Each has an advantage in reducing transaction costs by reducing the gap between consumers and producers, ultimately transforming consumers into producers; and

- Each benefits on the demand-side by creating greater value for participants by facilitating and tapping the energy of groups forming networks.

B. Supply-Side Efficiency

The advantage in transformation process rests on two factors. First, each set of activities accomplishes greater coordination by applying a combination of technological and human coordination (see Exhibit 2).
Mesh wireless communications rely more on embedding cooperation in the technology – in algorithms and protocols of communications devices.

Open source, in contrast, relies more on human cooperation, greatly enhanced by digital communications, although code embodies knowledge, just as algorithms do.

Peer-to-peer networks made up of non-technologists stand between the two. Technology does much of the work, but people need to cooperate too. Most importantly, these networks survive with varying levels of human cooperation and skill.

Second, in each case, critical resources – spectrum, code, storage, bandwidth – are shared (see Exhibit 3). Sharing requires a process – a principle of cooperation or coordination that organizes the critical factors of production. The sharing of the resources creates significant efficiencies for the networked activities and confers benefits to the collaborating parties. The capacity of the network expands. The larger the benefits, the lower the costs; the easier it is to communicate, the more likely is collaboration.
C. TRANSACTION COSTS

All of these areas of collaboration also gain substantial advantage by transforming consumers into producers (see Exhibit 4). Reducing or removing the distinction between the user and the producer results in substantial transaction cost savings. The fit between what is produced and what is consumed is improved both because the consumer knows better what to produce and the interests of the consumer and the producer are better aligned (identical).

EXHIBIT 4: TRANSACTION COST SAVINGS WHEN USERS BECOME PRODUCERS

The importance of users being producers needs to be emphasized. Users have the locally specific and sticky knowledge of what they need or want. Transferring and translating that knowledge introduces inefficiency. Producers who are also users and volunteer for tasks that interest them inherently have a better understanding of the production problem and an ability to align expectation with
production. They have the locally specific knowledge necessary to solve problems. Second, there is an agency problem where consumers are not producers. The producer’s interest may not be in meeting the needs of individual consumers precisely.

Manufacturers are the agents of users with respect to new products and services. It is their job to develop and build what users want and need; they do not want the products for themselves. The trouble is that, when manufacturer’s incentives don’t match those of users – and they often do not – users end up paying an agency cost when they delegate design to manufacturers. A major part of this agency cost takes the form of being offered products that are not the best possible fit with users’ needs, even assuming that manufacturers know precisely what those needs are. Manufacturers want to spread their development costs over as many users as possible, which leads them to want to design products that are a close enough fit to induce purchase from many users rather than to design precisely what any particular user really wants.58

D. DEMAND-SIDE EFFICIENCY

The efficiency on the demand-side comes from group formation. I call this the demand side since the size of the network – the number of network members that can be reached – and the pattern of interactions dictate the value of the network to the members. The value of the network inheres in the number of connections that can be made and the possibilities for communications (and therefore commerce) that they open up, as noted above. It is also the case in all of these networks that users significantly self define the product space. In so doing, they create a second benefit, an increase in value, by selecting the groups to join and using the group to meet their needs.

Reed identifies three types of networks that create value (see Exhibit 5).

§ In the one-way broadcast network – the Sarnoff “push” network – the value is equal to the number of receivers that a single transmitter can reach. Reed uses a wire service as an example.

§ In the Metcalfe network, the center acts as an intermediary, linking nodes. Reed uses classified advertising as an example.

§ In the Group Forming Network or Reed Community, collateral communications can take place. The nodes can communicate with one another. Reed uses a chat group as an example.

The possible connections expand dramatically. Network optionality, when realized in group-formation, generates much greater value than traditional models.

Bob Metcalfe, inventor of the Ethernet, is known for pointing out that the total value of a communications network grows with the square of the number of devices or people it connects…
But many kinds of value are created within networks. While many kinds of value grow proportionally to network size and some grow proportionally to the square of the network size, I've discovered that some network structures create total value that can scale even faster than that. Networks that support the construction of communications groups create value that scales exponentially with network size, i.e. much more rapidly than Metcalfe’s square law. I will call such networks Group Forming Networks, or GFNs.59

Exhibit 6 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 N². The Reed community value is 2N. The key difference between the Metcalfe network and the Group Forming Network is multi-way communications.

In networks like the Internet, Group Forming Networks are an important additional kind of network capability. A GFN has functionality that directly enables and supports affiliations (such as interest groups, clubs, meetings, communities) among subsets of its customers. Group tools and technologies (also called community tools) such as user-defined mailing lists, chat rooms, discussion groups, buddy lists, team rooms, reading rooms, user groups, market makers, and auction hosts, all have a common theme – they allow small or large groups of network users to coalesce and to organize their communications around a common interest, issue, or goal. Sadly, the traditional telephone and broadcast/cable network frameworks provide no support for groups.60
The exponentiation increases value very quickly and it can be argued that the number of connections/communications will 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 set of the theoretically possible groups would dramatically increase the value or the network. In Exhibit 6, I include N-cubed to make this point.

E. 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 we have a new solution to the collective action problem, a new environment for human cooperation. Weber’s discussion of open source engages the issue of collective action directly.

This dynamic yields a twist on conventional collective action arguments, where large groups are less likely to generate collective goods. The conventional view coming down from Mancur Olsen is that the larger the group, the smaller the fraction of total group benefits any person acting in the group can expect to receive.
so that person gains more on the margin by allocating her effort toward a selfish pursuit. Second, the larger the group, the less likely there will be oligopolistic interaction that might help obtain the good – because any particular small group that wants to cooperate will again get a small fraction of the benefits. And finally, the larger the group is, the greater the costs of organizing it in a way that can compensate for either of these problems.

The twist is this: under conditions of antirivalness, as the size of the Internet-connected group increases, and there is a heterogeneous distribution of motivations with people who have a high level of interest and some resources to invest, then the large group is more likely, all things being equal, to provide the good than is a small group.\textsuperscript{61}

Weber’s twist on the collective action problem is geared to collaborative production of open source. It may be invoking too many conditions. Because open source is oriented around a common task, Weber needs heterogeneous, motivated individuals with resources. He offers a comprehensive framework to explain why the conditions will be met. von Hippel’s discussion of user-driven innovation supports Weber’s model by showing why individuals will volunteer, particularly the core group of lead users.

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 was the key facilitating innovation. It wiped away networking incompatibilities and the significance of geography, at least for sharing code. As a result, the Internet made it possible to scale the numbers of participants in a project… As the numbers scale and the network grows, the likelihood of proliferating weak ties – that is, pulling into the process people with very different sets of expertise and knowledge – goes up as well…

To simply share code over the Internet became a seamless process. As bandwidth increased over time, the Internet also enabled easy access to shared technical tools, such as bug databases and code versioning systems, that further reduced the barriers to entry for user programmers.…

What practice does reveal is that open source developers make enormous use of Internet-enabled communications to coordinate their behavior.\textsuperscript{62}

Viewed more broadly, ease of communications is seen as the critical change in the collective action context.

Evolving communications technologies affect several factors that used to distinguish effective collectives from ineffective ones. Technologies that reduce the cost of sending information long distances (or to many people) can reduce
organizational costs, increase noticeability, and make ineffective communicative networks effective. If group members’ interests are sufficiently common, or if they interact in contexts that induce them to share information, these technologies can also make selective incentives a more viable recruitment strategy. Evolving technologies, as a result, change which groups can and cannot act collectively; doing so in a way that undermines many widely held beliefs about the logic of collective action. In particular, evolving technologies can erase the disadvantages of being large – which should change the rule of thumb that many people use to distinguish latent groups from other kinds.63

It may well be that the literature on collective action was always too pessimistic. The study of common-pool resources cited earlier is rich with examples from physical space.

In CPR dilemmas where individuals do not know one another, cannot communicate effectively, and thus cannot develop agreements, norms, and sanctions, aggregate predictions derived from models of rational individuals in a noncooperative game receive substantial support. These are spare environments… In richer environments that vary from the institutionally sparse homeland of noncooperative game theory…. [s]imply allowing individuals to talk to one another is a sufficient change in the decision environment to make a substantial difference in behavior.64

The recognition of shared interest – the collective payoff that flows from cooperation – also plays a key role.

When substantial benefits can be gained by arriving at a joint plan of action for a series of future interactions, individuals may have in their repertoire of heuristics simple sharing rules to propose, backed up by the presumption that others will use something like a measured response. If in addition, individuals have learned how a monitoring and sanctioning system enhances the likelihood that agreements will be sustained, they are capable of setting up and operating their own enforcement mechanism.65

Appropriators of a common resource might take into account more than the individual benefits and cost they receive from following or breaking rules that coordinate resource use. If they include the opportunity costs of foregone joint benefits and the expected costs of developing new rules if detecting behavior leads to the breakdown of existing arrangements, appropriators may recognize incentives to maintain those arrangements by adopting a cooperative strategy over numerous iterations. 66

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 COLLABORATIVE PRODUCTION

A. Supply-side

1. Open Mesh Networks

David Reed has presented a rigorous analytic framework for mesh networks in the spectrum commons that demonstrates these economic characteristics. When devices help and act as repeaters, sharing and supporting communications between neighboring points, the total capacity of the system increases as devices are added. Depending on how well devices share, the per device capacity may decline, but at a slower rate than in the non-helping case.

Cooperative gain means that in a repeater network a given number of transmitters will have a higher carrying capacity (see Exhibit 7). The total capacity will be higher and the average capacity per repeater will be greater. If we were to calculate a cost curve (not shown), we would find that the cost per unit of capacity is lower for both total capacity and on a per station basis in the repeater network.

2. Open Source

The digital environment is particularly challenging for the production of a functional information good like software. By a functional information good, I mean a good that is used as an input to produce other goods or services that are consumed or used. Functional goods are not consumed for their intrinsic value, but are used to meet other needs. The value of the functional good is indirect, realized in the other goods and services that are directly consumed. Not only are functional information goods complex, but the needs they meet are complex and the resources they demand are diverse. With the spread of computing to diverse environments meeting an increasingly diverse set of needs becomes more challenging to the command and control structure of centralized bureaucratic organizations.

In the case of mesh communications in unlicensed spectrum we saw that the sharing of spectrum turns the (il)logic of collective action on its head in part because the technology “embeds coordination” in communications devices. In the case of open source software, “the 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. Indeed… the distinction between input (knowledge) and output (software) is somewhat amorphous because knowledge and software are not only the common (spontaneous) standards, but also the nonrivalrous network product being shared.”67 The capacity advantage of repeater networks in contrast to traditional spectrum models depicted above in Exhibit 7 occurs in open source projects based on the organization of human capital in collaborative networks because it allows sharing and exchange of information. Collaboration increases capacity and lowers cost (see Exhibit 8).

The environment of near zero cost communications and low cost, distributed computer intelligence has a particularly powerful impact when the machine intelligence at the edges of the
digital network combines with human intelligence that is highly skilled to produce information products. Programmers are the ideal operators of the nodes in this network.

With a vast array of diverse individuals available to address the complex problems of producing software, a vast pool of human resources is created. By drawing from this pool, the chances that someone, somewhere will have the necessary skills to solve a problem are increased. By keeping systems open and promoting interoperability, the chances that the solution will be made available to the project are increased. While the decentralized approach will encourage multiple attempts to solve a problem, the rapid and ubiquitous sharing of information means that once a solution is found, redundancy will be avoided. When a solution is chosen, everyone knows and moves on.

It becomes possible to bring a large base of dispersed human capital to bear on the complex, heterogeneous process of producing software because the transaction costs of communicating across time and space have declined and the basic equipment for conducting the project and communicating the results have become widely distributed. Effective and efficient problem solving is possible, but only if tasks, efforts and results can be shared.

**EXHIBIT 7:**
**SPECTRUM CAPACITY IN TRADITIONAL AND REPEATER NETWORKS**

![Graph showing spectrum capacity in traditional and repeater networks.](image)

3. Peer-to-Peer Networks

As hardware and communications costs declined and larger, faster PC’s penetrated the market, central servers and backbone capacity quickly became economic bottlenecks. The design principles of the Internet made it inevitable that software would seek to escape the central server bottleneck by tapping into the abundant resources available on the edges of the network. By building multi-level connectivity that adds redundancy, the network becomes more robust. By adding points of communications, it becomes more scalable.68

Peer-to-peer networks are part and parcel of the evolving communications infrastructure, one of the many changes the Internet has made possible.69 The immense carrying capacity of the current generation of peer-to-peer communications networks exists precisely because they are decentralized. The value of decentralized nodes that communicate can only be realized if they can communicate directly with one another. On the supply side, peer-to-peer communications networks are efficient, robust and scalable.70 As long as principles of open architecture prevail, efficient solutions will economize on scarce resources by exploiting more abundant resources.71

Rather than placing all bandwidth costs on the original distributor, with P2P technology the distribution cost is spread among millions. Spreading distribution costs gives content owners far more flexibility in making their works available to the public. P2P has empowered not only content providers, but also has spawned many new business applications that utilize distributed computing technology.72

The production and distribution of music have been the focal point of activity. The obvious reduction in search costs and improvement in information quality should lower total cost and increase demand. More importantly, from the artists’ point of view, the new technologies change the social relations of production. Peer-to-peer networks disintermediate the recording companies.

The sale of recorded music is a classic example of how middleman costs are undercut by Internet distribution. Well over half the cost of producing a CD is manufacturing, distribution and marketing costs, which could be largely replaced by electronic distribution of music files over the Internet.73 The costs of the centralized distribution system place a huge drag on the market. These costs could be all but eliminated with digital distribution. Another quarter of the costs – record company overhead and marketing – is vulnerable to sharp reduction in an environment that emphasizes horizontal structure and peer-to-peer communications. Thus, three-quarters of the costs and the central point of control could be eliminated, spelling the end of the highly skewed star system.

To put these numbers in stark relief, one author notes that the average price per CD in 2001 was about $17.99, while the cost of producing a CD in quantity was $0.50. The average amount an artist receives is $0.12.74 Others put the artist share somewhat higher, but not much more than a dollar, net of costs.75 Thus, the intermediaries that stand between the musician and the audience account for a huge part of the final price.
As a powerful new means of distribution and communication, it undermines the role of intermediaries. Producers of goods and services are finding new ways to deal directly with consumers, eliminating or reducing the role of middlemen. Consumers also are able to establish relations with one another, or to become producers in their own right.

C. THE DEMAND-SIDE

1. Open Mesh Networks

The benefit of open wireless networks lies primarily on the supply-side, but there is one sense in which group formation is important. In order to capture the full benefits of a spectrum commons, ad hoc mesh networks must be formed. To appreciate this, we must understand the demands of an ad hoc mesh network (see Exhibit 9).

The radio will have to detect use of the spectrum, assess the quality of service it needs for its own transmission, and ascertain whether transmitting in the space in that manner can be accomplished in conformance with the established rules of non-interference. The different adjectives applied to emerging radio technology can be defined in terms of those functions. “The elements that make a

EXHIBIT 8: BENEFITS OF OPEN SOURCE

Large base of human capital -> Mobilizing skills, Finding Bugs
Free, casual Entry -> More Members, better versed, Seamless handoff
Users as producers -> Refine align expectations
Peer review -> Professional development, Productivity, Quality
Values and norms -> Reduce risk, Reduce rework
Incremental release, Early and often -> Standardization, Reuse, Less time to market, Maintenance saving, Quality
Open Discussion (e.g. web sites, trackers) -> Lower admin. Costs, Accumulation of knowledge
Collaborative Environments ->
radio cognitive (from a spectrum utilization perspective) are the ones that identify, remember, update, share opportunity information, and exploit the opportunity information with adapted transmission to avoid causing harmful interference. Starting from the bottom left of Exhibit 9 and working to the top right, each of the concepts subsumes the one below as a complex network is constructed.

An agile radio is a software-defined radio, one that can change its use of frequencies, power, and modulation without changing its hardware. In this sense, it is agile – as it can move around the spectrum. Frequency agile radios are a subset of the broader category, which can be agile in other dimensions (power and perhaps wave form). An agile, software defined radio is the basic building block of the new communications network.

Adding sensors and a reasoning system to an agile radio gives us a cognitive, intelligent, or smart radio. Cognitive radios are aware. They sense the network and store the rules of the road. Embedded logical systems allow them to decide when to transmit without breaking the law.

Cognitive radios can be combined into systems. The cognitive system adds a layer of intelligence to the communications network by looking at the overall topography of the network.

A meshed wireless network integrates cognitive radios as access points and relay nodes (repeaters) in a unique architecture for spectrum use. It treats cognitive radios as an asset that can be used to support any communication, not just the ones in which the radio is the origin or the final destination of the message.

An ad hoc network allows radios to join and leave the network as they desire. The network is designed to adapt to the nodes that are available. The ad hoc, mesh network architecture brings new capabilities because it is not only “a form of self-configuring wireless networking in which connections are transient and formed in an ad hoc as-needed basis,” but it also enables “self-healing networking in which routing continues in the face of broken nodes or connections.”

When we rise to the level of cognitive radio systems in ad hoc mesh networks, the fundamental nature of the undertaking changes. This dynamic space bears little resemblance to the spectrum facility as it existed throughout most of the twentieth century. Several authors liken this architecture to the Internet based on an end-to-end architecture.

The concept of a cognitive radio located in an ad hoc mesh network crystallizes the knowledge revolution that is taking place, the ability of human intelligence to build incredibly complex, replicable networks in which coordination is embedded. At the core of the network is the reasoner, embedded intelligence.

A reasoner is a software process that uses a logical system to infer formal conclusions form logical assertions. It is able to formally prove or falsify a hypothesis, and is capable of inferring knowledge...

Inferring statements from other statements requires a structured and machine understandable base for representing knowledge about radio communications.
Such a knowledge base has to be constructed by human domain experts, before the machines will be able to interpret, consume, reuse, and eventually extent knowledge. For this, semantics are needed to define truth and valuations: so-called radio semantics…

Knowledge must be represented in a machine understandable way… that allows not only first-order logics, but also higher-order, class-based reasoning. 80

2. Open Source

A group of peers is at the core of the success of open source. Peer review of output plays a key role at both the institutional and individual levels. Individually, peer review among programmers
promotes professional development and motivates participation. It turns out that authorship, but not ownership, plays an important role. Institutionally, peer review promotes quality by vetting output across a large audience.

The open source process is a peer review driven process based on (peer) community-wide collaboration, with shared tools and access for all members of the community. To effectuate a broad peer review process that is focused on a specific product in a timely manner, the projects rely on open communications and discussion of frequent releases and parallel testing. Open discussion is encouraged through mail lists, websites, Wikis, and collaborative tools. Standardization and reuse become extremely important; complete information is available to all members of the community. To ensure that everyone is on the same page, frequent releases and builds of programs are made available.

Open communications takes place in the context of a clear set of group values (norms) by which to evaluate the product that is the object of the communications. Social commitment—a broad category that includes altruism—and ideological motives also come into play. A substantial number of participants in open source projects are motivated by a desire to do good. Some are motivated by a desire to combat proprietary code, which is seen as exploitative and antisocial.

3. Peer-to-Peer

The demand-side of peer-to-peer communications networks encourages three different forms of relationships directly between individuals—exchange, viral communications, and collaboration. The searchability of the network and the direct relationships between nodes fosters exchange between equals. As the capacity for networks to facilitate exchange increases, they exhibit classic demand-side economies of scale, or network effects. However, peer-to-peer networks exhibit much more.

Two-way communications establish a new relationship between artists and fans. Digital age fan clubs narrow the distance. Viral communications and collaboration enhance the ability to market and expand the ability to innovate. Peer-to-peer collaboration can be anonymous, were individuals sequentially add to or modify a product, or it can be interactive co-production as in open source.

At the same time that the new technology changes the relationship between artists and audiences, weakening the hold of recording companies and their star system because “there is a greater probability of discovering other high quality music items by lesser known artists with the new technology.” The ability to sample “is an information-pull technology, a substitute to marketing and promotion, an information-push technology.” As the cost structure of the industry changes through the adoption of digital technologies, performance improves, since “variable costs relative to fixed costs are more important for music downloads than for CDs. This suggests that acts with a smaller audience can succeed in the digital music market. As a consequence, we could observe more music diversity and a less skewed distribution of sales among artists.” In fact, we do observe this pattern. The payoff for artists and society is increasing diversity.

More interestingly, artists and publishers may benefit differently from the network effects generated by the number of those who buy legal copies and those who obtain illegal recordings… If the demand for, say, live performances is enhanced
by the “popularity” of the artists generated from the number of distributed recordings (legal and illegal copies combined), then we obtain the conditions under which publishers of recorded media may lose for piracy, whereas artists may gain from piracy.88

The ultimate basis for a new mode of production is to generate resources and satisfy needs more effectively that its alternatives. Combining the supply and demand-side characteristics of collaborative production yields precisely this advantage, as shown in Exhibit 10. But the value of these technologies goes well beyond the realm of economics.
IV. CONCLUSION

This analysis provides a platform for a number of further analyses. Specific policies to promote collaborative production in spectrum, network architecture, and intellectual property can be examined. The efforts of the incumbents to slow or undermine the advance of the alternative can be examined in terms of the resource flows that they interdict with court cases and legislation. From the broad perspective taken in this paper, however, a more important line of further analysis would engage the political economy of the new mode of production.

To succeed, a mode of production cannot rest solely on technology and the economy. It must also institutionalize itself across other dimensions of society, including civic institutions and the polity (see Exhibit 11). The potential to institutionalize a coherent political economy exists. Although this paper has focused on economic issues, there is no doubt that this mode of production has desirable political characteristics. Open wireless and peer-to-peer networks that allow each repeater and each user to be a speaker expands speakers’ rights and holds the promise of invigorating First Amendment rights. In an earlier age, De la Sol called communications technologies of liberation. Lessig calls the emerging digital media technologies of expression. It can argued that the political and social institutions that would be consistent with the collaborative mode of production promote values in those realms to an extent that equals or exceeds the benefits of collaborative production in the economic realm.

EXHIBIT 11: THE POLITICAL ECONOMY OF OPEN SOURCE

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Modalities of Regulation</th>
<th>Digital Communications Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>of Social Order</td>
<td></td>
<td>(Internet, Web Peer-to-Peer, Open Source, Unlicensed Spectrum)</td>
</tr>
<tr>
<td>Technology</td>
<td>Architecture</td>
<td>Distributed Intelligence, Intensive Open Communications</td>
</tr>
<tr>
<td>Economy</td>
<td>Market</td>
<td>Decentralized, Collaborative, Cooperative, Property as Distribution, not exclusion</td>
</tr>
<tr>
<td>Civic</td>
<td>Norms</td>
<td>Voluntary, Participatory, Transparency, Non-hierarchical, Non-Discriminatory</td>
</tr>
<tr>
<td>Polity</td>
<td>Law</td>
<td>Deliberation, Non-coercive, Egalitarian, Responsive</td>
</tr>
</tbody>
</table>

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ENDNOTES

1 See Y. Benkler, “From Consumers To Users: Shifting The Deeper Structure Of Regulation Toward Sustainable Commons And User Access,” Federal Communications Law Journal, 56, 2000 for an early, scholarly discussion of this transformation.


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4 P.J. Weiser, and Dale N. Hatfield. Policing the Spectrum Commons. P. 1.


9 P. Levine, The Internet and Civil Society (University of Maryland, Institute for Philosophy and Public Policy, 2000).


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22 North: 118… 133


25 Besanko: G-7

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31 Id., p. 102


38 M. Cooper, “Making the Network Connection,” in M. Cooper (Ed.), *Open Architecture as Communications Policy* (Stanford: Center for Internet and Society, 2004).


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44 D. P. Reed, Comment for FCC Spectrum Policy Task Force on Spectrum Policy, p. 10.

45 Y. Benkler, *Open Spectrum Policy*, NYU School of Law, N.D.


52 Arora, Fosfuri and Gamardella, p. 112.
53 Arora, Fosfuri and Gamardella, p. 113.
54 “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 (E. von Hippel, “Economics Of Product Development By Users, p. 105).”
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60 Id., p. 3.
63 Lupia and Sin, p. 329.
64 Ostrom, Gardner and Walker, p. 320-321.
65 Id., p. 220.
66 Id., p. 296
75 Fisher, 2004, Appendix A.
80 Berleman, Mangold and Walke, p. 3.
83 Id., p. 38.
87 Gopal, Bhattacharjee and Sanders, pp. 33-37.