Law, Innovation and Collaboration in Networked Economy and Society

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Abstract

Over the past twenty-five years, social science research in diverse fields has shifted its best explanations of innovation from (a) atomistic invention and development by individuals, corporate or natural, to networked learning; (b) market-based innovation focused on material self-interest to interaction between market and non-market practices under diverse motivations; and (c) property rights exclusively to interaction between property and commons. These shifts have profound implications for how we must think about law and innovation. Patents, copyrights, non-compete agreements and trade secret laws are all optimized for an increasingly obsolete worldview. Strong intellectual property impedes, rather than facilitates, innovation when we understand that knowledge flows in learning networks, mixing market and non-market models and motivations, and weaving commons with property are central to the innovation process.

Keywords: innovation; networks; peer production; free and open source software; commons; motivational diversity

I. Three Basic Shifts

Three major shifts in our understanding of innovation have a profound influence on how we think about law and innovation. Over the past twenty-five years, research has shifted focus from (a) atomistic invention and development by individuals, corporate or natural, to networked learning; (b) market-based innovation to interaction between market and non-market practices; and (c) property rights exclusively to interaction between property and commons.

The first shift concerns the relative importance of individual invention and development as opposed to knowledge sharing and incremental learning in communities of practice. One archetype is the image of Thomas Edison—a brilliant individual working tirelessly alone and achieving a major breakthrough, or Bell Labs or Apple under Steve Jobs—the single firm investing its profits in pursuit of innovation. The other archetype is the learning network. A diverse set of actors—firms, universities, or individuals—freely exchange techniques, questions, insights, and people, so as rapidly to harness the interaction between their diverse knowledge bases to move the field of innovation forward. Which of the two approaches is a better reflection of the history, present, and future of innovation is absolutely central to the question of how law interacts with innovation. If innovation is primarily a process of discrete contributions by individual actors (natural or corporate), then patent law must be evaluated from an incentives / access framework as seen by individual inventors. Antitrust law must proceed from assumptions about what market structures increase or decrease investment incentives for individual actors. Trade secret and non-compete contract law similarly reflect a need to develop and retain talent within discrete organizations. If innovation is primarily an emergent property of knowledge flows, sharing, and collective learning in communities of practice and knowledge networks, then these core levers of innovation law are mostly counterproductive (Lemley 2012).

The second question is how much of innovation is market-driven, and how much is driven by personal or social motivations and formal public investment. Again, Edison is the quintessential market-driven entrepreneur, as is Silicon Valley venture capitalism today. Whether the model is built on Schumpeter's concept of creative destruction and innovation driven by firms competing to control markets, or a more neoclassical conception of an individual competitive firm seeking higher returns from patent rents, much of the influential work from the 1950s to the 1990s focused on market actors and market incentives, and debates over the shape of the law took that assumption as central. The past twenty years of research have seen increasing recognition of the central role of individuals pursuing their own needs and interest, as well as a wide range of social motivations in addition to material self-interest. As the Internet decreased the cost of communications across time and space, social production became an increasingly important source of innovation. User innovation, peer production, and academia-industry collaborations, in turn, have come to play an increasingly important role in our understanding of innovation.

Even in the older literature, however, the incentives-access paradigm and the literature on sequential innovation recognized the role of commons, or the public domain, to innovation much more so than was admissible in analysis of other areas of economic activity. The newer literature on shared knowledge in communities of practice and non-market sources of innovation has a more direct emphasis on open commons, and the interaction between commons and property as a core institutional design topic.

Overall, the trend of the literature of the past two decades has been to increase the emphasis on knowledge flows and sharing, whether market or non-market; on non-market sources of innovation, relative to market sources; and on commons and their interaction with property, rather than on property as the core. In part, this reflects the fact that in networked society knowledge sharing and collaboration are simpler and cheaper, and a high rate of innovation demands the rapid learning of open innovation rather than the more measured exploitation-focused proprietary strategies. In part, the change reflects a broader intellectual trend, away from the atomistic, self-interested rational actor models that came to dominate much of academic debate from the 1970s to the 1990s and towards increased recognition of cooperative, pro-social dynamics in networks as more central to human behavior.

II. Individual Invention or Learning Networks?

a. Background: atomistic models of the latter twentieth century

Mid-century economics of innovation largely divided into two camps: neoclassical and neo-Schumpeterian. Both camps focused on innovation in firms, and sought to understand the incentives for investing in innovation derived from the problem that information is a public good.

The neo-Schumpeterian school focused on rents that market power gives firms, and hence on market structure. If a market is too competitive, firms lack the rents necessary to invest in innovation (Scherer 1992; Carlsson 2003). The general understanding in this literature is that markets with few large firms and many small firms yapping at their heels are optimal (Aghion et al. 2009). In much of this work, patents are secondary considerations, although endogenous growth models (Romer 1990) suggested that patents and market concentration were rough substitutes as sources of rents that could support innovation. Most empirical research, however, has found no significant measurable impact of patents on innovation (Lerner 2009; Cohen 2010; Boldrin & Levine 2013), although the question continues to be contested (Aghion et. al 2015). As for antitrust, neo-Schumpeterian theory best explains the AT&T case in the 1980s and the Microsoft cases in the 1990s. Having a monopoly based on the network characteristics of an industry or being first to market is not itself cause for liability; indeed, it reflects the desired innovation resulting in concentration that permits the innovator to extract rents to cover its innovation costs. But it is a violation to leverage that advantage into other fields where innovation by others threatened the original advantage of the monopolist, as AT&T did for long distance, customer premises equipment, and information services, or Microsoft tried to do for web browsers and Java (Katz & Shapiro 1999).

The neo-classical school *locus classicus* is Arrow's (1962) characterization of the tradeoff between incentives and access: because of the nonrivalry of information, the more that property succeeds in letting the inventor capture the full value of its invention, the lower the welfare in society from the innovation, and the higher the burden on follow-on innovators who build on the earlier innovation. This basic insight was developed in the concept of cumulative innovation, or “on the shoulders of giants” effect (Scotchmer 1991). The legal implication was that excessively strong IP rights had a negative effect on downstream innovation by increasing its costs. This cumulative innovation argument became the foundation for arguments about “anticommons” effects in biomedical innovation (Heller & Eisenberg 1998) or patent thickets as barriers to innovation (Shapiro 2001). Still operating within the framework of a single firm, Cohen & Leventhal's (1989) major contribution on the absorptive capacity to a firm's innovation shifted the focus to how a single firm's R&D strategy prepared it to learn from neighbors. This created a bridge from firm-focused analysis to the learning network.

Learning in networks

The 1980s saw the emergence of the claim that innovation emerged from knowledge-sharing in networks. Piore & Sabel's *The Second Industrial Divide* (1984) described craft-based practice and knowledge sharing among small firms as an alternative to mass production. Early studies of knowledge sharing among networks of firms included development of 19th century pig iron in one UK region (Allen 1983); small mills in the American steel industry (von Hippel 1987), and spillover effects among neighboring firms (Jaffe 1986). Powell then generalized networks as a fundamental alternative organizational model to markets and hierarchies (Powell 1990), and applied it with collaborators to innovation in high technology industries (Powell et al. 1996, Owen-Smith & Powell 2004). As a methodology, network analysis shifts the focus from the individual actor (human or firm) as the fundamental unit of analysis to the relationship as the fundamental unit of analysis. Padgett & Powell’s distillation is: “in the short run, actors make relations, but in the long run, relations make actors” (2012). This property of networks fundamentally alters the legal tradeoff between rules that facilitate appropriation and those that support learning and innovation.

Historical studies of innovation in networks have contributed to understanding innovation as a collaborative, networked activity. Bessen & Nuvolari (2016) collect studies that document historical instances of knowledge sharing. One class of studies describes knowledge sharing in a community as the unsung hero that complemented an oft-credited heroic inventor. Examples include extensive sharing of biological insights and seeds as a precondition to advances in wheat production usually associated with individual mechanical inventions, like the McCormick reaper (Olmstead & Rhode 2008); or the rich knowledge exchange networks surrounding heavier-than-air flight (Meyer 2013). Some studies show no heroic inventor, relying purely on knowledge networks. Bessen and Nuvolari mention the Dutch fluyt, the vehicle of early Dutch commercial development, and Dutch mills critical in early industrialization (Davids 2008). Finally, there is a category of studies that finds communities of practice emerging despite a patented invention, sometime in opposition to the patent holder or after a critical patent expires, where the community of practice contributed to a dramatic increase in the quality and utility of the invention more rapidly and extensively than the original, patented, heroic inventor was able or willing to do. The steam engine and its development in Cornwall after Watt's patent expired is the prime example (Nuvolari 2004; Nuvolari & Verspagen 2007). Other challenges to the heroic invention story cover the spinning jenny (Allen 2009) and Bessemer Steel (Meyer 2003). This historical literature gives a much larger role of "collective invention" in the foundational story of the commercial and industrial revolutions (Allen 2009).

In foundational work in economic geography, Saxenian (1996) explored the success of Silicon Valley relative to Route 128 in the 1980s, arguing that Silicon Valley thrived because individuals circulated among firms, forming new startups and new connections among individuals with complementary insights across firm boundaries through social interactions. Later studies support the claim that mobility of knowledge workers across firms is a major vector for knowledge diffusion and an accelerator of innovation (Samila & Sorenson 2011). Azoulay, Graff Zivin, and Sampat (2011) study 9,483 movements of elite academic life scientists between institutions. Using patent and article citations, they show that article-to-article citations at origin institutions are unaffected by major scientists' movements. Article-to-patent and patent-to-patent citations, however, decline in the region the superstar scientists left, and increase in the region to which scientists moved. Their data suggest that in the bridge between academia and industrial innovation, personal relations matter significantly, and that knowledge diffusion in networks is carried by individuals and seems to be tacit and communicated in person.

Economic geography more broadly has focused on spillovers and knowledge flows in urban settings. Breschi & Lenzi (2016) provide an overview. When people live in close proximity, formal and informal opportunities for communicating create both rapid diffusion of ideas and novel combinations of ideas that increase the rate of innovation and adoption of productivity-enhancing innovation (Jaffe, Trajtenberg & Henderson 1993). Mark Granovetter (1973) early emphasized the role of weak and strong social ties, or bridging and bonding social capital. The former facilitate exploration of new opportunities, the latter underwrite trust and cooperation. Owen-Smith and Powell showed these interacting effects in the Boston biotechnology sectors, among firms and across the firm-academia boundary (2004). Critically, both features permit individuals to be densely connected across geographic or social distance, thereby increasing the rate at which signals propagate in a social network (Watts & Strogatz 1998). Schilling & Phelps (2007) show inventor networks that exhibit high bonding and bridging as particularly effective for knowledge creation and diffusion. Breschi & Lenzi (2016) study 331 metropolitan statistical areas in the U.S., finding that a combination of dense local cliques within cities complimented by social proximity to inventors outside the city contribute to increasing knowledge creation in the city.

The central role of individual mobility among firms and academic institutions creates an explicit legal tradeoff between strengthening learning networks and strengthening single-firm appropriation. Hyde (1998, 2003) and Gilson (1999) argued that the primary explanation for the divergence Saxenian observed were legal constraints on worker mobility. Unlike Massachusetts, California does not enforce non-compete agreements, and its courts narrowed trade secret doctrines. This made it impossible for California firms to prevent employees from circulating to new firms, and led them to adopt social norms that encouraged circulation of knowledge as a way of drawing young talent. A legal regime that privileged free flow of knowledge among firms outperformed one that empowered firms to enclose their intellectual resources once you understood that innovation emerged from knowledge flows in communities of practice rather than from individual firm stand-alone investments.

Extensive work since then has confirmed these foundational insights (Lobel 2013). Michigan's 1985 switch from non-enforcement to enforcement of non-competes offered a as a natural experiment. Marx, Strumsky, and Fleming found that Michigan's policy changes resulted in a brain drain from Michigan (2009, Marx et al. 2015). Belenzon & Schankerman (2013) find that a state's enforcement of non-compete clauses decreases instate knowledge spillovers, as well as increasing knowledge workers' out-migration. Samila & Sorenson (2011) find that states that do not enforce non-competes or restrict its enforcement see higher returns to local VC funding: strongly enforced non-competes inhibit formation of spin-offs and startups. Png and Samila extend this to the doctrine of "inevitable disclosure" in trade secret law, which is functionally equivalent to enforcing a non-compete—it prohibits competitors from hiring former employees of their competitors whose employment would lead to "inevitable disclosure" of the former employer's trade secret. They find that when courts rejected this doctrine, states saw a 15% increase in the mobility of scientists and engineers to other firms or startups (Png & Samila 2013).

Non-compete and trade secret doctrine are the clearest examples of how shifting from an atomistic view to a network view of innovation leads to directly opposing policy implications. If innovation is an isolated practice, stronger limitations on employee mobility are important institutional means to permit the centers of innovation—firms—to appropriate the returns from their investments. If innovation is an emergent property of networks of individuals and organizations (commercial firms and universities), such that discrete nodes become more innovative and productive when they are part of networks of learning with a high rate of knowledge flows, then laws that impede mobility dampen the learning effects of the network. The empirical evidence as of this writing tends to support the network view over the atomistic view.

c. Social production: FOSS, peer production, and user innovation

As academic recognition of learning networks across firm and university boundaries developed, the Internet was making communications among networks of individuals drastically cheaper and easier. When technology dropped the cost of communications and widely distributed the material capital necessary for knowledge work, it allowed individuals to share designs and incremental improvements with each other. These individuals, in turn, were able to pool their knowledge and resources, and coordinate action toward shared goals, without the mediation of firm hierarchies or markets (Benkler 2002a; Baldwin & von Hippel 2010). Innovations dependent on high concentrated capital costs remained in firms, but the change in transactions costs opened the door to an alternative organizational form. From free and open source software (FOSS), through Wikipedia to video journalism, peer production plays a more significant role in the information production environment than was theoretically admissible by economic models of motivation and organization prevailing at the turn of the millennium.

Early economic analysis of peer production focused on software (Ghosh 1998; Lerner & Tirole 2002), with some early work treating it as part of online cooperation generally (Ghosh 1998; Kollock 1999; Moglen 1999). Of particular relevance was work that focused on the comparative advantages of peer production as an organizational and institutional model of collaborative innovation and information production in bringing diverse individuals to bear on a problem, using diverse motivations, unencumbered by constraints imposed by property or managerial hierarchy (Benkler 2002a; von Hippel & von Krogh 2003). The critical innovation was in the licensing and organizational form—because materials were available as an open access commons, any person who saw a problem could identify it, any person who had the time, training, and insight to offer a solution or response could offer it, and the network of participants could vet, test, and evaluate the quality of the various solutions. The result has been measurable success in software, in particular, where deployment and performance measurements are easiest to obtain. By 2010 40% of firms reported using open source software (Lerner & Schankerman 2010). Measuring a single (albeit major) software product, Apache Web Server, Greenstein and Nagle (2014) imputed a transaction value for instances of Apache (the most popular FOSS web server) by comparison to the nearest market substitute.

Using a range of possible scenarios, they suggest that Apache may account for between 1.3% and 8.7% of the capital stock of packaged software, and argue that the actual number is likely on the higher end of the distribution. Similarly, their calculations suggested that Apache installations alone carry an imputed value equal to between 8% and 40% of the enterprise and mainframe software market. These large values for a single measurable product lead them to define "digital dark matter" as information goods deployed without transactions or accounting, and to identify these goods as introducing a significant error term in our understanding of the sources of innovation. Beyond online information goods, von Hippel and collaborators documented a range of practices in which networks of users, from physicians developing diagnostic tools to farmers developing irrigation and mountain bikers developing bikes, are the lead innovators across a wide range of industries unrelated to information technology (von Hippel 2005; von Hippel 2016; Harhoff & Lakhani 2016). The impact is so central, Lakhani, Lifshitz, and Tushman argue, that managing the boundary of the firm in relations to these networks of peer production innovation is the core strategic challenge for firms, as low transactions costs make innovation in networks of individuals a major source of innovative insight (Lakhani et al. 2013).

Organizationally, peer production combines three core characteristics: (a) decentralization of conception and execution of problems and solutions, (b) harnessing diverse motivations, and (c) separation of governance and management from property and contract. The knowledge spillovers literature already hinted at the problems with a property-based understanding of innovation, and the peer production, FOSS, and user innovation literatures emphasize how commons-based institutional arrangements move to the forefront when we understand innovation as a property of networks, not a series of discrete outputs of individual actors. These reflect both a departure from the idea that property models are central, and a research focus on how networks of collaborating individuals govern themselves in the absence of either clear markets or formal hierarchies. The second point, the diversity of motivations, overlaps with the insights of the literature on knowledge spillovers, primarily in the prominence of universities in regional networks and the importance of tacit knowledge to explain why individual mobility appear to be so important to knowledge networks. Peer production, where governed properly, is particularly well adapted to integrate contributions from diversely motivated individuals, including incorporating insights from socially motivated contributors (Benkler 2002a; von Hippel 2016).

The separation of governance from property and contract has attracted diverse mission-oriented groups to an open network, open access model for organizing information production and exchange. The original model was the Free Software Foundation, founded by Richard Stallman, which developed the GNU General Public License (GPL) as an anchor for a model of production that combined practical innovation concerns with a foundational ethical commitment to prevent property from becoming a point of control by owners against users (Stallman 1985; Colman & Hill 2005; Kelty 2008). Creative Commons was the organization founded to extend this model to free culture generally (Lessig 2004). It has become a central institutional model for the access to knowledge movement (Kapczynski 2008).

d. open innovation

Open innovation is a strain of management science that applied the lessons of networked innovation to collaboration among businesses. It follows Henry Chesbrough's book, *Open Innovation* (Chesbrough 2003). Its primary distinguishing feature is that it takes the perspective of the individual firm's strategic goal attainment (Chesbrough 2012). Given its focus on the firm's strategic goals, rather than welfare or growth, the open innovation literature has been friendlier to strong intellectual property rights than have other strands of network learning. Most directly, the work recommended formal patents as an assurance for firms that they would be able to appropriate the returns from investment in innovation (West & Gallagher 2006; Dahlander & Gann 2010). Given the obvious divergence between a firm's strategic interest in appropriating rents and a society's interest in increasing innovation at the social level, the optimal policy from a social perspective may diverge from the rent-maximizing policy from the individual firm's perspective (West & Lakhani 2008).

Even within a single organization's strategy, however, the tradeoff between strong intellectual property and open collaboration is not clear cut. O'Reilly and Tushman's emphasis on the importance of ambidextrous organizations—able to explore new opportunities while exploiting existing opportunities—offers a useful framework (O'Reilly & Tushman 2004). Critically, the strength of intellectual property for the firm's own strategic goals reflects that firm's choice trading off exploration and exploitation. Firms focused on developing dynamic capabilities to continuously explore in a rapidly moving innovation stream will benefit from more porous firm boundaries (Lakhani et al. 2013). Newer work within the open innovation literature indeed suggests that firms, even when entitled to protect their innovations through strong patents or copyrights, nonetheless freely reveal it for a variety of strategic benefits—building reputation, gaining market share, growing the market, or inviting reciprocal exchange for potential collaborators (West et al. 2014, reviewing literature). In a special issue of *Research Policy* dedicated to open innovation, the two essays primarily dedicated to measuring the effects of formal patents and appropriation mechanisms suggest a closer alignment between the social measures of innovation and private measures. Laursen and Salter find that while some formal protection increases revealing, high protection is associated with lower levels of collaboration and open innovation (Laursen & Salter 2014). Henkel and collaborators (2014) focus on the way in which computer component manufacturers shifted from a high focus on appropriability through assertion of IP rights, to waiving IP rights in software drivers to elicit more and better collaborations. Du et al. (2014) suggest that innovation in firms that rely on academic science collaborations perform better under loosely-managed collaborations. These more recent works, despite continued work supporting strong appropriability (see Zobel et al. 2016), suggest that the early focus on strong IP may be a holdover from an era that more generally saw IP as a core strategic imperative, and had not yet incorporated the benefits open commons, or shared resources in reciprocal, collaborative dynamics.

Parallel to the question of formal patents or copyrights rights is the question of formal contracting. Gilson, Sabel, and Scott (2011, 2013) offer the foundational studies of relational contracting that underlie open innovation among firms. They argue that the rate of change has driven firms away from vertically-integrate innovation processes toward collaboration across firm boundaries, and to develop new forms of contracts to do so. Because rapid change implies substantial uncertainty (rather than predictable risk) it requires continuous readjustment over time. While risk enables crisp formality ex-ante, simply allocating the expected probabilities, uncertainty demands continuous learning and adaptation, leading to informality. Firms responded to this need by developing "braided" contracts, weaving formal and informal elements of the contract to guide consensual readjustments of the relationship over time rather than setting crisp terms for later judicial enforcement. The innovative contractual forms allow actors to self-organize, share resources in self-governing commons, and set governance protocols, processes, and infrastructures to enable multi-actor collaborations. Other work has sought to refine and document the internal dynamics and diversity of these practices. Bozovic and Hadfield rely on interviews with 30 California businesses to study in more detail the formal aspects of the contracts. The claim that formal contracts and formal reasoning are used by these firms "to coordinate beliefs about what constitutes a breach of a highly ambiguous set of obligations" (Bozovic & Hadfield 2015). This coordination, in turn, provides "scaffolding" that induces compliance with what is, despite the apparent formality, a relational contract. Jennejohn studies court cases involving enforcement of such contracts, and finds substantial variation from the original observations of Gilson et al. (Jennejohn 2016). The variation, however, does not suggest formality or strict boundaries, but rather a greater diversity of forms of collaboration, responding to more multi-dimensional benefits and challenges of inter-firm collaboration in open innovation settings.

e. Relational learning - conclusion

Across a range of disciplines the past thirty years have seen a gradual shift from focusing on innovation as an atomistic activity to seeing innovation as an emergent property of networks of learning. Relations ranging from mere co-presence and spillovers to structured collaboration and cooperation, formal and informal, appear to be the primary driver of innovation. As the Internet made communications easier, search and discovery, collaboration, and relational learning increased in scale, scope, and geographic dispersion. New practices that would have been intellectually inadmissible as plausible organizational strategies before the 2000s—like FOSS or Wikipedia—became measurable reality. Intellectual reorientation drove studies that were open to observing relations and cooperation, and these in turn drove reorientation of business strategy as well, increasing the range of firms exploring open, collaborative forms of innovative strategy, and sharing intellectual resources in commons. Some of this work suggests that strong intellectual property simply increases impedance in innovation networks, thereby imposing a drag on innovation and the flow of knowledge and creative recombination within these networks. Some focuses on semi-porous intellectual property regimes as levers with which firms can trade off rapid learning for exploitation, but even this literature cannot claim that from a social perspective, stronger intellectual property is better. Similarly, other areas of law, in particular contract, that excessively formalize enforcement and impose terms understood from a perspective purely of arms-length bargaining may harm, rather than help, innovation. This is true whether contractual enforcement limits mobility of workers who are the vectors of embodied tacit knowledge, or whether it excessively formalizes relations that require substantial good faith collaboration through continuous informal negotiation.

III. Market and Non-Market Innovation under Motivational Diversity

The quest to understand the relative importance of market-oriented as opposed to socially-oriented behavior in the invention and innovation process is longstanding. The policy significance is obvious. Exclusive rights, like patents, strong non-competes, or trade secrets, benefit only market-oriented innovation activities, and among those, only exclusive appropriation strategies rather than any of the diverse appropriation strategies that do not depend on exclusivity. Analyses that ignore this diversity of appropriation strategies and motivations therefore systematically overstate the benefits and understate the costs of any given level of intellectual property protection (Benkler 2002b).

The most common framing of this dichotomy concerns the role of academic science in the invention and innovation process (Nelson 1959; Mowery et al. 2004). Universities have generally played a central role in studies of learning networks (Powell et al. 1996).

Legal scholarship raised concern that commercialization would undermine the exploratory role of universities and Mertonian norms of science (Eisenberg 1987; Rai 1999). Empirical investigations since then describe diversity of strategies within academia rather than convergence on market norms (Owen-Smith & Powell 2004; Mowery et al. 2004), but there is little meaningful dispute that non-market motivations and organizational forms play an important role in academic research and in the innovation system as a whole.

In the binary state/market framing, funding comes from either markets or governments. The standard economic position in this framework is that government should fund early stage research that is foundational, exploratory, with high spillovers, while industry should fund applied implementations (Nelson 1959; Arrow 1962; Aghion et al. 2008). Beyond this classic binary framing, however, innovation research has explored more diverse models. The smallest modification is the addition of philanthropic funding—which alters the source of funding, but not the underlying actors in the networks of innovation. In the United States, early science funding by foundations created from the First Gilded Age—Carnegie and Rockefeller—was overshadowed by federal investment, which increased substantially following World War II and continued at high levels throughout the Cold War. This role for the state (Bush 1945) was consistent with the then-prevailing New Deal ideology. The Great Inflation and the turn to neoliberalism reoriented federal policy toward market-based investment, and growing deficits placed political and fiscal pressure on science funding. At the same time, the Second Gilded Age saw the very wealthiest individuals capture a large share of the economy's productivity growth, and new philanthropy has joined old philanthropy to provide about 30% of university research funding for both foundational and translational research (Murray 2012).

A more dramatic break with the binary state-market framework was the recognition of innovation in social practices outside market-based firms or state-funded institutions. Eric von Hippel's groundbreaking work on user innovation emphasized that much of innovation was pursued by users—people who need a solution to a problem and find it—

rather than producers seeking to sell their innovations (von Hippel 1976, 1988, 2005). These ranged from scientists developing scientific instruments, through contractors developing new insulation, to mountain bike enthusiasts innovating on their bikes to pursue their passion. The basic model was the same. True invention required rich practical knowledge about domains of practice and the challenges and opportunities they present. Firms, however, cannot afford to engage in unstructured inquiry about what is needed or how to solve it in sufficient granularity across an undefined range of practices. Instead, practitioners encounter problems, innovate and iterate on solutions to these problems, freely share them among themselves, and only after users come up with the solution that makes both the problem and its solutions obvious will commercial producers come along and "productize" the innovation. Producers are better at standardizing, packaging, and perhaps servicing a new product after users have invented it, but users will be the primary source of invention. The work has spawned an entire epistemic community within the field of innovation. Harhoff & Lakhani (2016) provide a good starting point to explore this literature. The literature received a boost with the emergence of FOSS development, which allowed for rich detailed studies of user innovation practices in networks (e.g. von Hippel & von Krogh 2003). Much of the earlier work in this vein did not distinguish between users who are amateurs and those who are market actors. An automobile manufacturer innovating on machine tools for its components was a "user," because it innovated to get the use value not to sell the innovation. As the work developed and communications costs dropped, the literature began to emphasize user communities, which were now better able to use CAD software to create and share designs online and increase the rate and scope of innovation relative to earlier days (Baldwin & von Hippel 2010). von Hippel has more recently focused on innovation carried on purely by non-market users who freely share their knowledge and have no intent or pathway to sell it (von Hippel 2016). In a series of studies with collaborators, he has also sought to quantify user innovation, suggesting that both small and medium enterprise innovation (Gault & von Hippel 2009; de Jong et al 2009) and household innovation (von Hippel et al. 2009) presented significant portions of innovative activities in a range of advanced economies.

As user innovation and the peer production literatures began to overlap, it became clear that a major advantage of commons-based peer production was its capacity to harness diverse pro-social motivations (Benkler 2002a, Osterloh et al. 2002). Early work on motivation in FOSS developed motivation analyses that could easily be assimilated to standard economics models—like reputational gain, use value, or skills acquisition (Ghosh 1998, Lerner & Tirole 2002). Survey-based work, however, disclosed more diverse self-reported motivations (Lakhani & Wolf 2005; David & Shapiro 2008), spawning extensive work on cataloging and understanding the interactions among diverse motivations (von Krogh et al. 2012) provide a comprehensive survey of work characterizing motivations in FOSS; Benkler et al 2015 review work on motivations in peer production more generally). Newer work has focused increasingly on field observations and experimental designs (Antin et al. 2012; Halfaker et al. 2013). The most important insights provided by some of this newer work are that contributors act for different reasons, and that theories based on a single uniform motivational model (whether material or social) are likely to mischaracterize the motivational dynamics. Moreover, motivations differ both within individual contributors over time, and between contributors, and are influenced by context and framing. These observations regarding diverse motivations in peer production interacts with the broad empirical literature on motivation crowding out, or the non-separability of motivations (Bowles 2016). That literature has made clear that designing interventions aimed to elicit a response from one type of motivation—say, paying to perform a task or emphasizing social status competition for completing it—has effects on other motivational vectors that may decrease, rather than increase, the desired behavior. This may render the interaction between different design interventions to introduce incentives and motivational interventions complex, leading to increases and decreases of contributions of different types, by different contributors, anchored in different cultures. Moreover, the baseline responses to, and interaction between, motivational interventions are not exogenous to the practice. Habituation in cooperative prosocial relations, and shared framing of social situations as appropriate for cooperative, prosocial engagement, may lead to a shift in the distribution of motivations and baseline reactions towards a more cooperative stance within the community of practice itself (Benkler & Nissenbaum 2006, Antin & Cheshire 2010, von Krogh et al. 2012).

While measurement remains spotty, it seems increasingly well supported that a significant amount of innovation activity carried out in society is driven by motivations that are not focused on commercial transactions, and utilizing organizational forms that are not oriented towards the market or based on proprietary appropriation as their source of funding or motivation. Because most current measurements of innovation use transactions, monetary expenditures by established firms, or patenting activities, we appear to be missing substantial volumes and value of innovation activity that simply is not counted. This measurement omission, in turn, skews our perspective of who the individuals and organizations who contribute to invention and innovation are, and what organizational, motivational, and institutional models they follow or are likely to be most useful to them. If legal rules are optimized for a system assumed to be composed of uniformly market-oriented, exclusive-rights-wielding actors, but the world in practice is composed of a substantial proportion of strategies that are non-market based, they will in practice yield systematically worse social welfare and innovation activity effects than predicted by models that assume homogenous actors and strategies.

IV. Commons and Property

The economics of innovation law have long emphasized the importance of open access commons. As Justice Brandeis put it, "[t]he general rule of law is, that the noblest of human productions—knowledge, truths ascertained, conceptions, and ideas—become, after voluntary communication to others, free as the air to common use." (*International News Serv. v. Associated Press*, 248 U.S. 215, 250 (1918) (Brandeis, J., dissenting)). The intellectual *zeitgeist* of the 1970s, the rise of rational actor model, the emphasis on tragedy of the commons and the failure of collective action, and a new-found confidence in free markets that marked the neoliberal moment saw the emergence of the idea of "intellectual property" as opposed to discrete areas of specialized law (patents, copyrights, trademarks) (Fisher 1999). Fed by a sustained political effort by major industry players around the international trade regime (Drahos & Braithwaite 2001), the legal regime entered a period of ratcheting up of the strength and enforcement of intellectual property just as the social sciences were coming to a recognition that innovation was likely a process that not only did not require, but was perhaps affirmatively harmed by excessively strong intellectual property protection (Lemley 2015). By the end of the first decade of the twenty-first century, however, a very different orientation had emerged, focused on the public domain (Boyle 2008), or more generally on the central role of commons.

Beginning in the 1990s, the term “the commons” emerged as an organizing concept for two critical insights. In the legal literature, Litman (1990) described how the public domain in copyright preserved a resource set for new works to build on. Samuelson (1990) emphasized the critical role of access to existing inputs in software, because incremental development was at the heart of software development. Boyle (1996) expanded these insights and located then in a political economy, Lemley (1997) criticized efforts to strengthen intellectual property rights based on the “on the shoulders of giants” effect and the significance of positive externalities in innovation, and Cohen (1998) underscored the unique economics of information to negate the analogy of physical property to support stronger IP rights. My own work emphasized the role of open access commons as the institutional foundation for open and decentralized innovation driven by distributed experimentation and diversity by market and non-market actors (Benkler 1998), in particular allowing new forms of collaboration in networks (Benkler 2002a). Lessig (2001) and I (Benkler 2000) argued for preserving the commons at every layer of the Internet in the name of distributed innovation and expression. Frischmann tied this work to earlier work by Carol Rose, and synthesized it into a theory of commons in infrastructure based on demand-side economies of scale (Frischmann 2005). Arising at the same time, although not focused on innovation and specifically rejecting open access commons as a core model, Ostrom and others documented and systematized long-standing common property regimes used, for example, in irrigation districts, pastures, or fishing grounds, which sustained cooperation over centuries without government hierarchy or individual property rights (Ostrom 1990).

The two schools of the commons—the Ostrom school and the open commons school—complemented each other in defining the limitations of property and markets as mechanisms for learning (Benkler 2017). The Ostrom school, in particular the Institutional Analysis and Development framework (Ostrom 2011) observed that the diversity of local eco-systems meant that efforts to standardize resource packets for market exchange tended to abstract from the complexity of local ecological conditions, and were as lossy as translating resource systems for bureaucratic management. Local practical knowledge, often tacit or translated into religious or other customary practices, elicited better information about optimal resource management for the particular resource set and aligned motivations among the owners of common property in the common-pool resource better than would a standard individual property rights regime designed for arms-length market exchange. These practices, in turn, offered a foundation for studying governance without state hierarchy or individual property-based markets. This school emphasized local knowledge, structured governance without government or markets, tacit knowledge, and cooperation. The open commons school, focused on fast moving, complex modern economies rather than on longstanding common resource pools, emphasized the networked learning and cooperation aspects of open commons. It resolved uncertainty not by emphasizing rich local knowledge over time, but by emphasizing decentralized innovation and rapid experimentation, which increase the diversity of potential sources of diagnosis of problems and proposals of solutions, and open exchange and free revealing to enhance the flows of problem definitions and solutions among the universe of potential innovators. It too focused on cooperation and diverse motivation, as well as on the benefits of social incremental learning, but in open systems, rather than in closed common property regimes.

Over the past fifteen years, there has been increasing crossover between the two schools (Hess 2008). Most directly, Madison, Frischmann, and Strandburg (2010, 2014) explicitly called for, and have orchestrated through conferences, a research community focused on applying the IAD framework to diverse knowledge commons, from genomic data, through rare disease clinical research data, to online citizen science like Galaxy Zoo (Madison 2014). The same research community has also begun to create crossovers to the literature on historical and organizational work on knowledge flows—bringing under the umbrella of knowledge commons work on the development of the airplane, or national security funded research in the inter-war period (Meyer 2014). Other work explores diverse knowledge commons such as the International Comprehensive Ocean and Atmosphere (ICOADS) (Weber 2015) commons in biomedical research (Contreras 2016; Lee 2016), as well as in the Global Influenza Surveillance Network (Kapczynski 2011). Parallel to the work in the IAD vein, Reichman and Uhlir have offered detailed studies of “contractually reconstructed commons:” the practice of creating particularly scientific commons through various licensing devices that create special institutional innovations to manage the boundary between exploration and exploitation in the sciences (Reichman & Uhlir 2003; Reichman, Dedeurwaerdere, and Uhlir 2016)

A rich vein of detailed empirical work on governance of commons-based innovation is newer work on governance of peer-production. Directly linking to the IAD and the Ostrom school is Schweick and English's study of a broad range of FOSS projects, both market-based and nonmarket (Schweick & English 2012), and Fuster Morell mapping peer production (Fuster Morell 2014). FOSS provided a major focus of research on governance and organization of peer-production (see Crowston et al. 2012 for a review). Wikipedia offers another major site of study, with Reagle (2010) offering important book-length scholarly treatments. A recent review of work on organizational aspects of peer production identifies new directions in this vein (Benkler et. al 2015), emphasizing in particular ways in which structure re-emerges within peer-production communities. The work provides empirical exploration of how peer production develops organizational routines and practices that help it to negotiate the tension between full decentralization of innovation and the need for collective efficacy. Healy & Schussman (2003) argue that hierarchy may contribute to peer production success, and Keegan & Gergle (2010) and Shaw (2012) have documented gate-keeping behavior in peer production and suggested that it may benefit projects. Loubser (2010) and Shaw & Hill (2014) studying a cross section of wiki communities show that hierarchies tend to become more pronounced as peer production projects mature. Increasingly work is exploring the development of commons-based production in physical space, makerspaces and hackerspaces, where the practices and norms of online peer-production are jumping to real world innovation practices. (Kostakis 2014, Williams & Hall 2015). An example of this work is a study by Kostakis et al. (2016) describing the use of desktop fabrication (3D printing) with peer production to develop inexpensive, highly effective robotic hands and prosthetic limbs, and small wind turbines.

Substantial empirical work anchored in law and social norms explores how the absence of copyright or patents led diverse communities to developed norms of sharing and exclusion to govern their creative practices. These include case studies of fashion designers (& Raustiala Sprigman 2012), comedians (Oliar & Sprigman 2008), French chefs (Fauchart & von Hippel 2008), and a range of other practices that developed where, for historical reasons, law did not apply strong intellectual property rights. Raustiala & Sprigman (2016) offer a review and synthesis.

Complementing the shift from an atomistic understanding of innovation to a network conception of learning and the emergence of knowledge, and the growing evidence of the diversity of sources and motivations for innovation, the literature on the commons has developed a detailed institutional analysis of governance and cooperation without markets or hierarchies, whether states or firms. But there is no single "commons." Instead, there is a family of institutional arrangements whose core characteristic is the symmetric allocation of use privileges to an open class of users, subject to governance structures, whether formal or informal, not based on asymmetric rights to exclude. Commons emphasize the flow of information, reduce the institutional impedance to such flows, and in many cases anchor the practice in a set of social and ethical relations that facilitate the elicitation and practice of social motivations. They remove a major form of potential power in such cooperative endeavors—the proprietary claim that can be used by strategic actors to expropriate an unfair share of the overall gains created in a community of practice. In some cases, these commons arise by historical accident—where law has not covered a given activity or class of potential appropriation, like non-compete agreements. In some, it may arise by intentional policy choice, as in the case of data under American law. More recently, we have seen licensing practices, like the GNU

GPL or Creative Commons, leveraging background property rights to create a commons. The weight of this work supports a central role for commons in the institutional framework of innovation in the networked society.

V. Conclusion

The social science literature on innovation has, over the past two decades, emphasized knowledge flows and sharing, whether market or non-market, rather than atomistic innovation by heroic individuals or single firms. It has expanded the range of non-market sources of innovation from a focus on the state and state-funding, to a broader range of social practices—in particular by users and peer production networks online, operating on diverse motivations rather than simply maximizing self-interested monetary returns. Finally, the literature has increased its emphasis on the importance of the public domain, or open commons, relative to property, in knowledge production and innovation activities.

In part, the shift may reflect technological change. The Internet made communications across distances and organizational boundaries cheaper, while computers have made previously high-capital cost activities—like computer assisted design—widely available in the population. These technological developments have made it possible for larger networks of individuals to explore a larger opportunity space of collaborators, resources, and projects, and find others with whom to cooperate in pursuit of their shared goals. Widespread distribution of physical and human capital, complemented by diverse social motivations, has made it possible for new collaborations to emerge. These practices then enabled diversely motivated individuals to engage in remarkable efforts of social production, and to create direct competition between commons-based and property-based substitutes to the detriment of the latter.

But the change in social science also reflects a shift in intellectual frame. Much of the early work on learning networks was not about technologically-mediated networks, but about geographically- and institutionally-mediated networks. Northern Italian craft industries or Cleveland UK's pig-iron shops; Silicon Valley or Boston's biotech community, all offered early studies that shifted the view of innovation away from the single firm to the network of learning and mixed cooperative-competitive relations. These all preceded Internet-mediated cooperation, and relied on physical proximity and social norms and practices to connect the network. As network science itself has advanced, this intellectual reframing is likely at least as influential in shifting our perspective on innovation as are the technology-mediated changes in practice.

Debates over innovation law and policy, in turn, reflect this shift. While the 1980s and 1990s saw a rise in academic voices calling for stronger intellectual property rights across the board, much of the academic discipline has moved to a more skeptical stance. Nonetheless, much of present patents and copyright law, particularly as informed by the international trade and IP regime, was designed at the height of the atomistic, market-based intellectual moment. The academic work of the time legitimated rent-seeking lobbying by IP-owning firms, which then drove a ratcheting up of strong property rights without basis in empirical evidence. All three major shifts in the social science literature require skepticism about present levels of exclusive rights, and policymakers aiming to improve their innovation system should begin from the assumption that their exclusive rights regime may be too restrictive and create excessive impediments to knowledge flows relative to the appropriation benefits it confers.

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