Reconceptualizing the Institutional Foundations of Cumulative Innovation

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ABSTRACT

While some innovation scholars fear that the landscape of innovation is becoming more restricted due to an expansion of intellectual property rights, others show that innovation processes are becoming more open. The question which unites these disparate literatures is not whether intellectual property rights are more expanded or relaxed, but how do the conditions and rules that guide the access and use of an innovation affect others' ability to build upon it? If we take this question seriously, it suggests a new focus on the antecedents of cumulative innovation: disclosure, accessibility, and reciprocity. Provision of these conditions is affected by legal, technical, normative and organizational conditions. If knowledge accumulation is critical to economic growth, than we must evaluate how our institutions affect the degree to which innovators can work cumulatively. Thus, in designing effective foundations for cumulative innovation, the critical question is not whether to pursue a strategy that is more 'open' or 'closed', but rather how private contracts, public laws, norms and organizational solutions can be combined to support cumulative innovation among diverse parties. This is an outcome which should be of concern to both policymakers and scholars alike.

Refocusing the Debate

Proponents of the "open science and innovation" perspective fear that continued expansion of intellectual property rights and their stringent enforcement may harm future streams of innovation at a time when stand-alone innovations a rarity. Proponents of the "private property rights" perspective are concerned that without aggressively defending their intellectual property, creators will lack incentives to invest in innovation, particularly innovations with long gestation periods like biotechnology or unpredictable returns like entertainment.

We argue that this increasingly polarized debate between advocates of "private property rights" and "open science and innovation" neglects the very mechanisms that support cumulative innovation. While all innovation may be cumulative to some degree, the degree to which innovators can accumulate prior knowledge is critical to socio-economic progress - particularly in the creation of building block ideas critical to a range of sectors. We suggest that rather than argue whether innovation should be 'more open' or 'more closed', what we should examine are the conditions that permit cumulative innovation to occur.

In this policy brief, we define the cumulative innovation perspective and identify the conditions necessary for innovators to build on the work of others. With a few local experiments, we examine how legal and normative conditions change over time to support cumulative innovation. In doing so, we discover that innovators on the ground devise mechanisms to permit both open and private property approaches to co-exist. We conclude with two suggestions: 1) If the ability to innovate cumulatively is a policy concern, than policy makers may want to explicitly evaluate the regulatory impact of policy on innovators' ability to build on the work of others; and 2) If policymakers wish to foster cumulative innovation, then consideration of legal means alone may not be enough - organizational solutions to foster disclosure and access of common information resources may also be useful.

The Cumulative Innovation Perspective

It could easily be argued that all innovation is cumulative to the extent to which it builds and incorporates prior knowledge from diverse sources (e.g. Hargadon and Sutton, 1997; Fleming, 2001; Garud and Karnoe, 2003; Garud and Kumaraswamy, 2005). Scholars have long recognized that when we innovate, we stand on the shoulders of others (Merton 1973). However, innovators standing on the shoulders of others may have interests and rights that differ from the originators of those ideas (Katz and Shapiro, 1985; Scotchmer, 2004).

This is primarily because contributors to cumulative innovations may come from different sectors, which can exacerbate potential competing interests and make the need for new institutional arrangements more pressing (Rosenberg and Nelson, 1994; Nelson and Nelson, 2002; Murray 2006). Previous history shows how the interests of governments, firms, and universities can converge when pursuing path-breaking innovation (Nelson, 1986; Rosenberg and Nelson, 1994; Simcoe and Mowery, 2002; Simcoe, forthcoming), but that they can also diverge in the degree to which market versus public interests can be pursued in application (David, 2003; Nelson, 2004).

While scholars of science, innovation, and economics have long recognized that the accumulation of knowledge is vital to socio-economic progress, they have been less quick to examine how conflicting rights among innovators with different interests are handled in the pursuit of cumulative innovation (Scotchmer,1991; 1996, 2004; an intriguing exception). The cumulative innovation perspective explicitly considers the challenges inherent in accumulating knowledge from disparate parties. Such a perspective examines the social, normative and legal institutional arrangements that allow diverse parties to disclose, access and build upon one another's ideas. It shifts attention from 'how open or closed should we be?' to 'who is able to share, reuse, and build upon knowledge?' and, most importantly, 'under what conditions?'

The overarching question that we pose is: *How do the conditions or rules surrounding the access and use of an innovation affect others' ability to innovate cumulatively?* This agenda moves beyond the design of legal mechanisms such as the patent system to consider the host of institutions that can balance the rights and interests of innovators as they stand on one another's shoulders. This is crucial because the accumulation of knowledge is vital to economic growth (Romer, 1990; Ashion and Howitt, 1999; Ashion et al, 1997). Yet, knowledge accumulation is not an inherent property of the innovation process itself. Rather, it can either be supported or limited by the context in which innovation occurs (Mokyr 2004). Indeed it is only when we acknowledge that cumulative innovation is an essentially *behavioral* process that we can fully examine the role of institutions and norms in shaping cumulative innovation.

Conditions Enabling Cumulative Innovation

To understand the conditions that foster an innovator's ability to innovate cumulatively, we identify the minimally sufficient conditions that can either foster (or inhibit) the accumulation of disparate 'pieces of' knowledge. First, in order to cumulatively build upon ideas that "came before", an innovator must know of it; this requires <u>disclosure</u> on the part of prior generations. Second, the innovator must be able to <u>access</u> these ideas in order to understand to combine them into a cumulative innovation. Third, both of these conditions depend upon <u>rewards,</u> not only to encourage earlier innovators to disclose their ideas but also to encourage them to provide access (to the information, materials or skill) so that later generations can usefully integrate these ideas. To show how these conditions are applied in practice, we draw upon examples from academic publishing, biotechnology and open source software.

Disclosure. Disclosure is the first step in initiating a cycle that enables cumulative innovation. Disclosure makes information about an innovation available to other innovators (for free or for a price), but does not provide access to reuse it or modify it. Disclosure alone is therefore a necessary but insufficient condition for knowledge accumulation. Normative, organizational and legal mechanisms may affect an innovator's willingness or ability to share their ideas. These mechanisms may be informal – as simple as a reciprocal exchange relationship among academic colleagues (Crane 1969) or prior co-workers (Saxenian 1996; Almeida and Kogut 1999), or they may be supported by formal arrangements (such as academic journals), or legal structures (such as Non Disclosure Agreements (NDAs) or patents).

For example, to acquire a patent, an innovator must disclose enough to "allow one skilled in the art" to replicate the claims described in the patent and cite prior art. Disclosure is however a matter of degree and as scholars of tacit knowledge have articulated, "full" and "meaningful" disclosure may require more than simply a "text". In order for that knowledge to be actionable, it may require access to materials, know-how, translation or the sharing of expertise (Collins 1974; Polanyi 1967; Brown and Duguid 1991; 2000; 2001; Carlile 2004).

Access. We distinguish disclosure from access because the mere act of disclosure does not specify the terms under which follow-on innovators can engage in two distinctive (but related) activities: i) explore, understand and practice the ideas and ii) build on and combine the idea into a new innovation. The first type, reuse access, implicitly grants 'reuse rights' and allows others to experiment and understand how those ideas were developed or produced. The second type, recombinative access, explicitly provides permission to not only reuse those ideas but to recombine them. To build on the knowledge developed by someone else, both types are required: one must understand how the original knowledge was developed and have access to the various inputs (tools, materials, information, techniques) in order to make use of them.

By managing both types of access, early generations of innovators impose control over the use of their ideas by later generations. Innovators can control both types of access through the non-exclusive use of normative, technical and legal means. For example, innovators who rely upon the Digital Millenium Copyright Act (DMCA) use two layers of enforcement to restrict recombinative access: legal and technical. First, hardware can be engineered to restrict follow-on innovators from accessing copyrighted works – limiting reuse access. Second, the DMCA reinforces this barrier by restricting follow-on innovators from reengineering or bypassing technical barriers - restricting recombinative access (Samuelson, 2001; Felten, 2002).

In the case of software, open source code provides reuse access through technical means: An informed reader of the source code can understand how it was developed and figure out how to modify that code. However, to have the *right* to modify that code, recombinative access must also be granted through legal means (typically though a software license) that allows the follow-on innovator to accumulate the ideas embedded in that source code with his own.

Innovators who tightly manage reuse and recombinative access can develop a competitive advantage that may be disruptive to those interested in generating follow-on innovations. "Platform leaders" like Intel, Microsoft, Palm, and Cisco (Gawer and Cusumano 2002) provide selective access to parts of their platform technologies to allow other firms to develop complementary innovations. Some countries, such as France, have viewed access control of platforms in terms of national interests. France has taken steps to mandate access to closed, proprietary platforms (such as Apple's iTunes) with the aim of creating a more level innovation playing field[1]. Thus, the management of access crosses technical, political, organizational and legal boundaries and may be the most contested antecedent condition of cumulative innovation.

Rewards. Lastly, to encourage innovators to disclose their ideas and provide access to others, they should be assured some form of reward. This may be intrinsic, but typically also includes remunerative, or reciprocal rewards from later innovators. For example, in academia, networks of collaborators exchange knowledge, techniques and materials in return for shared recognition. Similarly, while many open source software communities allow their work to be freely used, modified, and distributed, most open source licenses request that those who build on their work appropriately recognize the community's prior contributions (O'Mahony 2003; Rosen 2005).

In this manner, normative and legal arrangements can be used in concert. For example, when free or open source software is covered by the Gnu General Public License (GPL), a follow-on innovator who incorporates that software into their new product and distributes it must also distribute their source code (Stallman 1999; O'Mahony 2003; Rosen 2005). This license reinforces norms of the free software community by requiring reciprocity of access and effectively prevents expropriation of future derivations of GPL licensed code (Stallman, 1999; O'Mahony 2003; Rosen 2005).

In biotechnology, patents and licenses with 'reach-through' rights are an important way in which first generation innovators extract rewards from second generation innovators. 'Reach-through' clauses allow first generation innovators to collect royalties from the future stream of derived works. But as the GNU GPL demonstrates, 'reach-through rights' to next generation innovators can be used to extract either remunerative or reciprocal gain. Thus, the ability of second generation innovators to recognize or reward first generation innovators without too much difficulty is an important determinant of cumulative innovation - for this may affect a

[1] At the time of this writing, French lawmakers supported a draft bill headed for the Senate ruling that closed and proprietary music platforms are anti-competitive and mandating access across providers. This ruling would affect providers of closed music platforms like Apple's iTunes. http://news.bbc.co.uk/2/hi/technology/4833010.stm

first generation innovator's willingness to disclose or provide access to their innovation. However, rewards in this context, should be construed broadly.

As these examples illustrate, these three minimally sufficient requirements for cumulative innovation can be supported through technical, legal and normative arrangements. Inside organizations, the social structures and norms of particular work groups and communities of practice Knorr-Cetina, 1999; Brown and Duguid, 2000; 2001; Bechky, 2003; Hargadon and Bechky, 2006) may affect the degree to which disclosure and access are rewarded and practiced. For example, Nerker and Paruchuri (2003) suggest that innovators' structural position in networks affects the degree to which their ideas are reused and built upon. While these local conditions may vary, with the antecedents for cumulative innovation in mind, scholars and policymakers can more precisely evaluate how a specific mechanism can affect the degree to which cumulative innovation can occur.

Local Experiments to Foster Cumulative Innovation Across Sectors

While some scholars have been concerned with the introduction of private practices into the public realm (focused on patenting in academic science), others have been focused on the introduction of open practices into the private realm (focused on the open source software model). Rather than view these as divergent phenomena, we argue that they are evidence of local innovators experimenting with hybrid models to foster cumulative innovation. In this "rich and fertile middle ground", elements of both open and private property approaches to innovation are recombined (von Hippel and von Krough 2003). To illustrate how innovators on the ground are constructing new systems to enable disparate parties from both public and private sectors to build on each other's work, we provide two empirical examples from the worlds of biotechnology and open source software.

Biotechnology Example: Building on the Oncomouse: The Oncomouse is one of the first so-called "animal models" (animals with a predisposition to a particular disease) of cancer. Scientists inserted a cancer gene into a normal mouse, rendering the mouse highly susceptible to cancer. This provided a means to test new cancer drugs and has proved to be an important building block for innovation in the life sciences.

The Oncomouse was developed by geneticists at Harvard with research funds from the DuPont Corporation. Under the terms of the grant, DuPont had the right to any commercializable inventions that came out of academic laboratories. With encouragement from DuPont, Harvard filed a patent on the Oncomouse. Four years later, when it was granted in 1988, DuPont signed an exclusive license; giving the firm full and exclusive rights over the Oncomouse. DuPont, following its traditional practice of extracting economic value from its investment, crafted terms for those wished to use the mice. These terms included: A high price per mouse, a price for the license, a share of any commercial breakthroughs made using the Oncomouse in the form of “reach through rights” to follow-on inventions, restrictions on breeding, oversight of any projects using the mouse and publication oversight. While these terms applied to both commercial and academic scientists, academic scientists were exempt from licensing fees.

The response of the commercial community – specifically scientists in the pharmaceutical and biotechnology companies who wished to use the mice in their drug development strategies were initially mixed. Many found the reach through rights too costly. Firms worried about what has been called “royalty stacking”: this arises when a firm must share its profits from a particular project (typically a drug) with so many other parties (each of whom claims a royalty fraction of the final benefits) that the program becomes economically unviable. As other tools for drug development began to diffuse into the commercial sector, DuPont began to lower its royalty rates and reduce the cost of the license.

However the academic community was “outraged” over the conditions imposed by DuPont. DuPont had not anticipated that academic users would object to terms that they considered “free” (there was no licensing fee for academics). They failed to recognize that many of the other terms – breeding restrictions, a prohibition on exchange and publication review were at odds with academic used to gaining access to research mice for follow-on research with few stipulations. According to observers, “the grumbling reached insurrection proportions after a meeting [of academics] at Cold Spring Harbor” in August 1992 (Anderson 1993). What followed was a lengthy negotiation between DuPont and the Director of the National Institutes of Health who stepped in at the behest of the academic community.

It took until 1999 for the two sides to find common ground. When an agreement was reached, DuPont stated that it “is committed to making [Oncomouse] available to the academic community” (quoted in Marshall 2000). In the face of strong normative challenges, the firm came to appreciate that legal rights could not easily be upheld without sustaining considerable financial and reputational costs. They established a new university-level agreement with fewer access restrictions. This license adapted to public norms, allowing full access for follow-on innovators who were then able to proceed without the shadow of the law shaping their research agenda. DuPont abandoned their claims to reach through rights, allowing scientists to share mice with one another, albeit under the condition that the university receiving the mouse signed an Oncomouse license.

What DuPont came to realize was that to maximize use of the Oncomouse in scientific research and speed its acceptance as a research tool, the firm needed to establish terms and conditions for recombinative access that could meet the different needs of various constituents. As one academic scientist described the problem:

> I won’t reject a mouse because of complex conditions, but it slows the process down and if there is a choice well sometimes its easier to do it yourself if you possibly can. This is exactly what happened with DuPont, we just kept doing

> things ourselves and that made it much more difficult to compare our work. I think it really slowed down the adoption of mice by industry too because just at the time we should have been generating all the basic information to make this a standard model, we were slowed down.

DuPont resolved these tensions by establishing differentiated access terms. Commercial users now work with traditional licensing conditions (in part because it provided them with clarity of ownership and access rights), while academic users have open access. This new triaged approach is increasingly widespread as a mechanism to extend access to research tools and accelerate their acceptance by both academic and commercial innovators. In addition, DuPont designated a neutral organization, the Jackson Labs, to help manage the distribution of the mouse – an organizational solution designed to explicitly foster reuse of the Oncomouse.

Integrating norms, laws and organizations to foster cross sector innovation. In the case of the Oncomouse, laws and private contracts were modified to adapt to public norms and foster cumulative innovation among private and public actors. This recombination was then organizationally reinforced. In the following example from the open source software community, public norms were adapted with private mechanisms to create a community that can integrate contributions from public and private actors and similarly reinforced.

Open Source Example - The Apache http Webserver. The Apache http webserver is a software program that accepts http requests from a web browser and 'serves' a webpage to the requester. Next to Linux, the Apache webserver is one of the most popular open-source projects: used by over two-thirds of the 80 million websites regularly surveyed[2]. Apache's success may be well known, but its unique institutional history is less appreciated. Apache is based on the HyperText Transfer Protocol (http) server developed at the National Center for Supercomputing Applications (NCSA), an NSF funded center at the University of Illinois at Urbana-Champaign. In accordance with the terms of NSF funding, the project's code base was placed in the public domain and made freely available. After policy changes allowed the Internet to permit commercial use in 1994, demand for the program increased dramatically.

However, the server's development stalled when several NCSA administrators left to pursue commercial opportunities. Web developers around the world began independently updating the server for their own needs but no one at the NCSA integrated these improvements into the code base. Developers eager to explore the Internet's commercial potential posted their frustrations with the NCSA's lack of cumulative innovation on the project's mailing list.

[2] http://news.netcraft.com/archives/web_server_survey.html

> NCSA httpd 1.3 was originally released the better part of a year go. Since this release…there hasn't been a new release of Unix server software from NCSA…..(I)n the absence of further visible development from NCSA, a lot of people have found themselves fixing or extending 1.3 to meet their needs --- in the process fixing the same bugs and deficiencies over and over..(*posting to httpd list, February 27, 1995*)

The NCSA had provided both access and disclosure by providing the httpd source code which allowed others to improve and build upon the project, but it was not providing the organizational or institutional support needed to innovate in a cumulative fashion.

In response, eight developers communicating on the mail list decided to 'fork' (break away from) the NCSA code to integrate improvements to the code themselves (Fielding, 1999). They assumed the name 'the Apache' group because the server was 'patchy'. This group could take the NCSA code, modify it and re-release it under new terms since it was in the public domain. Nevertheless, in terms of reciprocity and rewards, what the group 'owed' the NCSA was uncertain: "We'd also be interested to know if/how NCSA would like to fit into this project and/or how we might be able to fit into theirs (if they want us)" (*posting to new httpd list, March 8, 1995*). With no response from the NCSA, the group built a revamped code base and protected it with an 'Apache' license. This license works much like an 'academic' software license, permitting free modification and reuse of the code as long as derived works cite the Apache project (Rosen, 2005). Thus, there is no legal requirement of reciprocity to contribute back to the project. Yet in this regard, *norms* of reciprocity prevailed - hundreds of contributors began donating bug fixes and system enhancement ideas almost immediately (Mockus et al, 2002). By the end of 1995, when Apache 1.0 was released[3], it was the number one Web server, constituting 36% of the market (Wall Street Journal 1998).

The Apache group has grown substantially since then and, with advice from a Fortune 500 firm, incorporated as a nonprofit (Apache Software Foundation or ASF) in June, 1999. The organization now provides organizational and legal support to the http server as well as over 30 other projects. Volunteer contributors assist in governance through project management committees and annually elect a board of directors. While still an informally self-managed group, the ASF has incorporated a number of formal legal and organization practices to help them to manage an increasingly sophisticated body of contributors from both commercial and non-commercial realms. For example, in a shift from informal reciprocal exchange to legal practices, contributors can no longer be anonymous. To ensure the provenance of their code, the Apache project now requires volunteer contributors to sign legal agreements that grant the ASF the specific legal right to use any code contributed. Such changes created modest changes to the community's academic style of collegiality.

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[3] Acknowledging that portions of the Apache software were based upon public domain software originally written at the NCSA, at the University of Illinois, Urbana-Champaign.

However, the introduction of commercial supporters created additional challenges to the ASF's ability to serve both public and commercial communities. Since the ASF formed, an entire industry selling related goods and services has emerged: one firm provides 70% of Fortune 100 and 50% of Fortune 500 firms with products and services that rely upon software managed by the ASF.[4] The ASF receives in-kind donations from Apple, HP, IBM and Sun.[5] Commercial support accelerated Apache's growth, but also created new concerns. As one Project Management Committee representative explained,

> You know we've always been fairly open meaning that if anyone wants to contribute a project to the incubator they are open to regardless of their corporate affiliation… However we have to walk a really fine line because the more corporate projects that we take on board the more perception becomes reality that we are fairly tight with commercial interests or we have these close relationships which does discourage more organic community projects…from wanting to join the Apache Foundation.

Community members recognized that catering too closely to commercial interests could compromise the ASF's commitment to open processes. And yet, ignoring the needs of commercial developers would limit the role that the Apache group's software could play in furthering cumulative innovation. One of the roles of the newly formed ASF is to help balance this tension.

Integrating norms and laws to foster cross sector innovation. Two things are worth noting from the Apache case. First, the emergence of a private voluntary organization to support cumulative innovation helped both sectors. The public sector was relieved from the burden of supporting the project. The private sector gained from the availability of a low cost webserver – from which they could create products and services. Second, this group began informally with only the norms on the http mailing list to guide them. Over ten years, they developed a widely respected organization that now manages open source projects donated by such firms as IBM and Sun. The integration of legal practices (a legal entity, governance process, a respected license) with the group's culture and norms of reciprocity has enhanced their ability to sustain the development of software that is routinely used in cumulative innovation for both public and private use. Like the Oncomouse, norms and laws were recombined and reinforced with an organization devoted to furthering cumulative innovation.

Discussion

The cumulative innovation approach examines how the conditions and rules surrounding the ability to access an innovation affect others' ability to innovate

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[4] For more information, see: http://www.covalent.net/.

[5] For more information, see: http://www.apache.org/foundation/thanks.html.

cumulatively. What is needed to innovate cumulatively? Our analysis suggests three minimally sufficient conditions: 1) disclosure; 2) access; and 3) rewards. Local norms and incentives may affect an innovator's willingness to innovate cumulatively but without these three conditions, it will be difficult to build on the work of others.

Our empirical examples show how innovators from both private and public sectors learned to collaborate over time by recombining laws and norms to support cumulative innovation. Neither party began with a deliberate agenda to improve the ability of innovators to work cumulatively. However, in both cases, parties discovered barriers to accumulation (either access restrictions or organizational constraints) and designed new systems that, in the case of the Oncoumouse, allow others greater access to build on the work of others and, in the case of the Apache webserver, explicitly foster integration of contributions from public and private parties. With the cumulative framework and these examples in mind, we identify three implications for policy makers: 1) Triage; 2) Organizations to Support Cumulative Innovation; and 3) Regulatory Impact.

1) Triage. One mechanism that is critical to building systems that explicitly support cumulative innovation is the ability to triage disclosure, access and rewards contingent on an innovator's use and purpose. By triaging rights and rewards, DuPont provided access to public users in a way that co-exists with commercial opportunities. The GNU General Public License accomplishes a similar objective in that it does not require every "hobbiest" to license their derived creations under the GNU GPL – only those who would distribute the code commercially (Rosen, 2005). The triaging of rights allows a more diverse group of actors to contribute to and sustain a shared resource for cumulative innovation than might otherwise be possible. In the case of DuPont, this differentiated approach was contested and only emerged over time. The challenge was to parse rights by types of usage in order to further innovation around shared interests without violating divergent interests.

Our examples suggest that legal tools can be used with greater elasticity than previously assumed, particularly within novel organizational contexts. Intellectual property rights are not good and bad in and of themselves. When used flexibly and in tandem with new organizational practices, they can be used to preserve access as well as they can be used to restrict it (O'Mahony 2003). Furthermore, they can be triaged to do both for different parties. Therefore it is not just the ownership of innovations or the lack thereof that shapes cumulative innovation. Rather, it is the conditions or rules surrounding the access and use of an innovation that affect others' ability to innovate cumulatively. The principle of triage explicitly acknowledges that a common system to support innovation can be used selectively to support actors innovating in both the private and public sectors.

2) Organizations to Support Cumulative Innovation. Both the Oncomouse and Apache examples illustrate how organizations come to be designed specifically to support cumulative innovation. When actors from public and private sectors are trying to innovate cumulatively, managing the boundaries of commercial and non-commercial action becomes essential. Such boundary work seems to be facilitated by the emergence of boundary organizations – intermediary organizations that enable actors from different social worlds to substantively and legally engage (O'Mahony and Bechky, 2006; Guston, 1999, 2000, 2001). As O'Mahony and Bechky (2006) argue, such organizations have characteristics amenable to the structures and interests of both actors but do not violate the foundational features of either. They help actors collaborate in ways that they might not otherwise be able. Recently, boundary organizations (in the form of non-profit foundations) have emerged in the areas of software, biotechnology, science and the arts to foster the development and distribution of resources to further cumulative innovation.

For example, biological resource centers reinforce norms of reciprocity by providing central depositories that manage access and certification of biological materials such as cell lines (Furman and Stern, 2006; Stern, 2004). Non-profit foundations are providing a neutral forum to foster cumulative innovation among open source software community and firm contributors (O'Mahony, 2003; 2005). New organizations such as creative commons, science commons and patent commons are focused on fostering diffusion and recombination of cultural artifacts and intellectual property (Lessig, 2004). Artists that want others to build on their work can use a creative commons license to specify the conditions under which their work can be reused. Other communities (such as ccmixtr.org) allow recording artists to deposit their work centrally in order to foster its cumulative reuse.

While preliminary evidence suggests that boundary organizations have a positive impact on cumulative innovation (see Furman and Stern 2006 for an exemplary study), much remains to be done. Future research should examine the effectiveness of different types of boundary organizations, and how different types of access, reuse, and recombinative rights affect the degree to which an innovation is reused, recombined, or diffused. How do such organizations affect follow-on innovators' ability to accumulate knowledge? How do they affect first generation innovator's incentives to invest in innovation? And finally, organizations designed to manage common information resources may be used as substitutes or as complements to laws and contracts. Thus we need to examine how such organizing mechanisms work relative to legal and contractual mechanisms.

3) Regulatory Impact. This essay has paid more attention to the normative and organizational conditions that affect cumulative innovation than the law, as these factors tend to lie in the shadow of the law However, we cannot neglect the role of law in affecting the degree to which innovators can build on the work of others. Particularly because that is typically the first element perceived to guide the opportunity to innovate cumulatively. Our research in the open source and biotechnology fields suggest that innovators in both of these areas come into frequent contact with legal constraints that too often do not take adequate consideration for their effects on knowledge accumulation. Thus, our recommendation is a simple one – we encourage policymakers to assess the impact that intellectual property policy has on knowledge accumulation. If the framework of cumulative innovation was embraced, than policymakers would consider more explicitly how to balance the rights of second generation innovators with first generation innovators. If cumulative innovation was a goal, this would also require assessing how policy affects disclosure, access and rewards. For without the ability to innovate cumulatively, much progress would be inhibited. However, as a number of local experiments suggest (many more than are captured here), creative institutional entrepreneurs can also craft organizational solutions to further cumulative innovation.

Conclusion

It has become increasingly clear that innovators have much to gain from shared knowledge upon which they can privately or publicly build. But this can only happen if competing agendas and rights can be reconciled – and this requires an institutional context that supports cumulative innovation. We therefore suggest that rather than explore whether innovators should be 'more open' or 'more closed', a more fruitful path evaluates how private contracts, public laws, and community norms and even organizations are used to support knowledge accumulation in ways that meet the divergent needs of multiple stakeholders. A growing number of local experiments suggest that both public and private actors are frustrated with limitations on their ability to innovate cumulatively. As a result, they are creating new organizing mechanisms that make equally creative use of legal and normative practices to enhance cumulative innovation in ways that balance the interests of first and second generation innovators and society as a whole. However, the extent to which these experiments will survive and proliferate remains unknown.

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