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Intellectual property, complex externalities, and the knowledge commons

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Abstract
Intellectual property (IP) can internalize positive externalities associated with the creation and discovery of ideas, thereby increasing investment in efforts to create and discover ideas. However, IP law also causes negative externalities. Strict IP rights raise the transaction costs associated with consuming and building on existing ideas. This causes a tragedy of the anticommons, in which valuable resources are underused and underdeveloped. By disincentivizing creative projects that build on existing ideas, IP protection, even if it increases *original* innovation, can inadvertently reduce the rate of *iterative* innovation. The net effect of IP law on innovation and welfare depends on the relative magnitude of these positive and negative externalities. We argue that the current regime probably suffers from excessive, and excessively rigid, IP protection. This motivates the search for institutional alternatives and complements. We suggest that a monocentric IP rights regime may not be the only, or the most efficient, way to internalize the positive externalities of innovation. The knowledge economy supports the emergence of diverse, polycentric forms of bottom-up self-governance, both market and community led, that entail the citizen coproduction of the norms and practices of intellectual creation and discovery.

Keywords Innovation · IP · Externalities · Transaction costs · Law and economics · Polycentricity

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1 Introduction

Intellectual property rights (henceforth IP), such as patents and copyrights, aim to encourage innovation, creativity, and productivity by giving publicly recognized creators and inventors exclusive, time-limited rights to their work. These limited rights (Posner, 2005), or quasi-monopolistic privileges (Blackstone, 2016),[1] are designed to enable creators to profit from their work. This may promote the development of new ideas and technologies. However, there are also counteracting negative externalities associated with IP rights. The exclusive rights granted by patents and copyrights can create barriers to entry for other companies and individuals who may want to build upon or use the patented or copyrighted work. This can stifle competition and reduce innovation in the long run. Unwieldy IP thickets, litigious IP trolls, and rent-seeking IP holders are among the recognized inefficiencies of the current system. The "optimal" level of IP protection is therefore a matter of legitimate controversy.

IP rights are often recognized for their contribution to innovation and growth (e.g., Romer, 1990, p. S82). But within economics today, no clear consensus exists (e.g., Depoorter & Menell, 2019; Depoorter et al., 2019; Dourado & Tabarrok, 2015). Even the staunchest defenders of the market economy disagree among themselves on the impact and desirability of IP laws (Epstein, 2001, 2005; Hayek, 2011; Machlup & Penrose, 1950; Martin, 2013, 2015; Slobodian, 2020). The situation remains largely the same today as it was when Machlup (1958, pp. 79–80) argued that "[n]o economist, on the basis of present knowledge, could possibly state with certainty that the patent system, as it now operates, confers a net benefit or a net loss upon society." Posner (2005, p. 59) reiterates and generalizes the point: "Unfortunately, economists do not know whether the existing system of intellectual property rights is, or for that matter whether any other system of intellectual property rights would be, a source of net social utility." While the net impact of IP on innovation remains uncertain, it plays an increasing central role in the global economy: "IP is big business today, so big that any mistakes in the legal design of the field could easily generate deleterious consequences. Getting it right has, if anything, become more important than it has ever been before" (Epstein, 2001, p. 803; see also Stiglitz, 2008, p. 1695).

Placing IP on a solid foundation requires getting *both* the general framework *and* many details right. Although our analysis has relevance for the normative debate around IP, our primary task is not normative but descriptive. Following the law and economics paradigm and expanding it, we offer a "positive analysis" tasked to evaluate the costs and benefits of intellectual property "as a means for promoting efficient allocation of resources" (Landes & Posner, 1989, p. 325; see also Landes & Posner, 2004; Posner, 2005). Our aim, here, is twofold. First, we provide an analytical account of the nature of the complex externalities involved in the knowledge economy that builds on and extends the Coasian transaction cost approach to the problem of externalities (Coase, 1960; Demsetz, 1967, 1996; Landes &

[1] The early British understanding of intellectual property rights, as discussed by Blackstone (2016, p. 276), viewed them as "royal patents of privilege" which grant producers "monopolies … by virtue of which a temporary property becomes vested" in the owner of the patent or copyright. The modern recognition of IP, in the form of "the right, which an author may be supposed to have in his own original literary compositions" (Blackstone 2016, p. 274), although it can appeal to support in some aspects of Roman and Common Law, thus came to full maturity in the top-down legislative context of "the statute of monopolies (…) which allows a royal patent of privilege to be granted for fourteen years to any inventor of a new manufacture, for the sole working or making of the same; by virtue whereof a temporary property becomes vested in the patentee" (Blackstone 2016, p. 276).

Posner, 1989; Papandreou, 1998; Posner, 2005) and the public choice literature on knowledge and IP (Buchanan & Yong, 2000; Dourado & Tabarrok, 2015; Shughart & Thomas, 2016). Second, we supplement this framework with the insights of the burgeoning literature on *Governing Knowledge Commons (GKC)* and other forms of polycentric institutional diversity (Ostrom, 1990, 1996, 2005, 2010, 2012; Lessig, 2001, 2004; Strandburg et al., 2006; Strandburg, 2008; Madison et al., 2010; Dekker & Kuchař, 2022). In so doing, we offer a novel synthetic framework that integrates the insights of the GKC framework with the emerging literature around public choice and complex externalities (Paniagua & Rayamajhee, 2021, 2023).

Existing research in the knowledge commons often discusses externalities as one social dilemma among many (Frischmann et al., 2014). Developing a deeper understanding of the positive and negative externalities of the knowledge economy, including the knowledge commons, is key to reassessing the legitimacy of IP rights. To that end, we analyze the complex externalities involved in knowledge production and explain how diverse polycentric governance arrangements, both market and community led, can help to internalize them.

Our framework challenges the assumption that incentives for innovation are roughly uniform across time and space and that IP rights should thus be treated as monolithic in their design and homogenous in their effects. They are not. On the basis of standard economic analysis, the *prima facie* economic case for, say, pharmaceutical patents is stronger than the case for computer software patents due to the different circumstances in the relevant industries (Boldrin & Levine, 2008; Kyle, 2020). We agree and generalize this point. Tackling the complex externalities of the knowledge economy requires paying attention to the context-sensitive nature of goods, services, and industries beyond the standard account. This may require reforming formal IP law to accommodate diversity beyond the common division into standardized patents, copyrights, and trademarks. Furthermore, different types of formal IP rights need to be compared against various (formal and informal) institutional alternatives. This highlights the value of comparative institutional analysis that is sensitive to real-world diversity.

The paper proceeds as follows. In Sect. 2, we explain how IP is intended to internalize positive externalities and why it also comes with negative externalities. In Sect. 3, we analyze two sources of negative institutional externalities associated with IP: the tragedy of the anticommons and rent-seeking. In Sect. 4, we analyze how polycentric self-governance helps internalize various externalities. Section 5 illustrates this using two case studies. Section 6 concludes.

2 The problem of externalities

Authors and inventors have invested in creating new knowledge. If someone else uses this knowledge without compensating them, they can be said to have benefited from a positive externality of their creative activity. Such freeriding reduces incentives to innovate. To address this issue, "intellectual property law … has internalization as its principal focus" (Harrison, 2005). Critics of this paradigm argue that the whole law and economics enterprise focused on "efficiency and wealth maximization" has set the IP debate on the wrong path (Palmer, 1989, p. 303). However, in this paper, we provisionally accept the efficiency standard whose sole normative concern is knowing what kind of an institutional IP regime

(if any) does more harm than good from the point of view of incentivizing innovation and advancing public welfare.[2]

IP law seeks to internalize the positive externality of innovation by granting the holders of an intellectual property right, such as a patent or copyright, a legally granted monopoly for a limited time. This internalizes the externality by forcing beneficiaries to either directly pay the creator or pay someone who has purchased licensing rights from the creator. In this way, IP law creates "a limited property rights system" capable of producing exclusive profits (Posner, 2005, p. 58). IP rights are often criticized for granting creators and discoverers special "privileges" (Bell, 2018) that allow them to extract quasi-monopolistic IP rents. Yet IP rights have also been characterized as pro-competitive property rights (Epstein, 2001, 2005, 2006; Mossoff, 2005, 2007, 2013). Mossoff (2005, p. 40) argues that IP rights falls under "the classic definition of property as the right to use, possess and dispose of one's possessions." Treating ideas as property can generate economic incentives for socially beneficial production and exchange in a manner sufficiently similar (if not wholly analogous) to physical property rights.[3] For example, Epstein (2005) argues that a property-like IP regime allows IP holders to take advantage of the same proven tools of market flexibility that the owners of physical property rights enjoy. As property, IP rights can become productively commodified, bundled, contracted, negotiated, and improved upon in the marketplace. As Baumol (2001, p. 730) puts it: "If the price is right, it will always pay the firm to license the use of [its IP] to others." Haber and Lamoreaux (2021, p. 23) thus argue that "because the value of a patent does not inhere in the award itself but rather in the market value of the resulting property right, patent systems foster the kind of decentralized, cumulative improvement that extends the frontiers of what is economically possible." In this way, the IP regime appears pro-competitive rather than (merely) monopolistic.

Treating IP rights as falling under standard stringent property rights protection is compatible with allowing regulators to intervene to keep the market competitive and fair. As Epstein (2001, p. 820) concedes, "the same kinds of qualifications that are appropriate to the exclusive rights to tangible property often carry over to intellectual property as well." This enables IP law to benefit from legal standards developed elsewhere. Treating IP as analogous to other forms of property rights is consistent with treating IP as a means to internalize positive externalities since one "primary function of property rights is that of guiding incentives to achieve a greater internalization of externalities" (Demsetz, 1967, p. 348).

But this effort to internalize positive externalities by enforcing property rights in ideas faces tradeoffs. As long as the deadweight loss of monopoly cannot be eliminated but only mitigated, there are negative externalities associated with "potential monopoly profits (and hence rent-seeking and resource misallocation)" (Landes & Posner, 1989, p. 361). Some critics (Boldrin & Levine, 2008, 2009; Kinsella, 2008; Stallman, 2006)

[2] In addition to this purely consequentialist normative framework, some scholars have argued for and against intellectual property rights on the basis of their impact on justice, fairness, autonomy, dignity, creator rights, and other moral considerations. The ultimate normative and public justification for the legitimate scope of IP rights regime must, of course, ultimately tackle the non-consequentialist dimensions of the IP regime, including the authors' and creators' rights perspectives. However, we have purposefully bracketed this dimension out of our analysis in order to better focus on unsettled questions in the IP *externalities* and *innovation* debate.

[3] Interestingly, Mossoff (2007, p. 1012) sees a historically salient development, or progress, from "English royal monopoly privileges" to the more property-like "American patent law." He contrasts the latter favorably to the former.

dismiss the term intellectual "property" as nothing but a "seductive mirage" (Stallman, 2006). But even many who accept the analogy between intellectual and physical property agree that IP has many of the characteristics of an "artificial monopoly" that "imposes deadweight social losses" (Bell, 2003, p. 271). Because IP establishes a legal monopoly right, the price will exceed that which would occur in a competitive market characterized by free entry. This deadweight loss can be conceptualized as a static inefficiency, which can be contrasted with the dynamic efficiency that may be gained due to the increased incentives for creative activity (Stiglitz, 2008). This deadweight loss of patents and copyrights can be significant since the marginal cost of the production and consumption of additional units is zero. The key task of "optimal" legislation is thus to approximate "marginal cost pricing" while securing sufficient returns on creative efforts (Posner, 2005, p. 58).

Intellectual property rights have mixed effects even from the point of view of dynamic efficiency since innovations can build upon one another in a virtuous cycle (Ridley, 2020; Teece, 2011). An excessively stringent IP regime may restrict the ability of one innovator to constructively build upon prior innovations in a productive and cost effective manner. Figure 1 illustrates these tradeoffs by showing how increases in the strength of formal IP protection initially increase innovation, but eventually can become so restrictive as to deter innovation.

So, while intellectual property rights can internalize positive externalities, they can also impose negative externalities. This is consistent with Coase's (1960) point that externality problems are reciprocal, reflecting a conflict between prospective resource users. When we consider the reciprocal nature of externalities, and the interaction between formal and informal institutions, intellectual property becomes a complex problem. In the next section, we discuss how the delicate balance between *insufficient* and *excessive* IP protection is affected by two institutional dangers: the *tragedy of the anticommons* and *rent-seeking*. These together show that excludable IP rights frequently underperform in the task of internalizing externalities.

3 Institutional externalities: the tragedy of the anticommons and IP rent-seeking

3.1 The tragedy of the anticommons

Exclusive IP rights can internalize the positive externalities of innovation by ensuring that it pays more to innovate than to freeride. At the same time, a *tragedy of the anticommons* in the knowledge economy results when too many people hold the right to exclude, thereby resulting in an IP resource being underutilized. Heller (1998) first developed the concept to analyze dysfunctions in the post-Soviet economy. Buchanan and Yong (2000) further formalized the concept and illustrated its analytical symmetry with the tragedy of the commons.

Heller and Eisenberg (1998, p. 698) show that a "proliferation of intellectual property rights upstream may be stifling life-saving innovations further downstream in the course of research and product development." They focus on the biotechnology industry where they observe "a spiral of overlapping patent claims in the hands of different owners, reaching ever further upstream in the course of biomedical research" (Heller & Eisenberg, 1998, p. 698). These types of overlapping patent claims, also known as "patent thickets," can deter

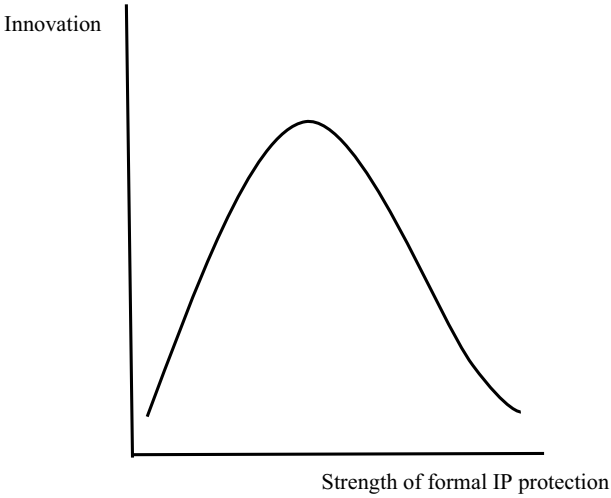

Fig. 1 Increasing formal IP strength can increase innovation but also reduce it beyond a certain point (adapted from Dourado & Tabarrok, 2015)

innovation in other sectors as well (Shapiro, 2001). This can lead to a "gridlock economy" (Heller, 2008). Tangled copyright claims have the same effect: "When copyright holders are numerous, it is costly to negotiate and reach agreements with all of them" (Akerlof et al., 2002, p. 13; Breyer, 1970, 2010).

High transaction costs are one symptom of excessive IP protection. Theoretically, "in a world of costless transactions, people could always avoid commons or anticommons tragedies by trading their rights" (Heller & Eisenberg, 1998, p. 698). But in practice, transaction costs exist, which means that the assignment of rights matters. When multiple overlapping rights to exclude are assigned, this can significantly raise the costs of iterative creative and innovative activities. "The resulting costs to society take two forms: the expenditure of resources to organize and complete these agreements, and a reduction in works created due to the higher costs of producing them" (Akerlof et al., 2002, p. 13). The more the utilization of existing IP requires the explicit approval of each affected IP rights holder, the higher the transaction costs of derivative innovation. This problem gets worse the more numerous, overlapping, and complex the IP regimes, rights holders, jurisdictions, and contractual entanglements become. This generates a vicious form of complex externalities where entangled innovators have to negotiate with each other for permission to build on existing innovations. Consider Breyer's (2010, p. 740) worry: "now that they're extending copyright to 100 years, has anybody thought that it's going to cost a lot of money to contact people to get permission? Or that many of the people who you need permission from are dead, or no one knows where they are (…)?" The transaction costs of contracting might be further exacerbated by psychological biases that have been observed experimentally by Buccafusco and Sprigman (2010, 2011).

The tragedy of the anticommons is likely to be especially severe for innovations that have many valuable downstream applications. As Paniagua and Rayamajhee (2023) show, externalities can be classified in terms of both their scale and the ease of assigning and enforcing property rights. To the extent that IP rights are easy to assign and enforce, and the positive externalities of innovation are large in scale, there is a theoretical case for strong IP rights. However, this is not automatically so, because both positive and negative externalities are affected by scale. The presence of many potential iterative innovators is a

sign of a larger scale of positive externalities to the innovation. However, that larger number of potential innovators also increases the transaction costs of negotiating to engage in iterative innovation. Larger scale positive externalities may therefore be correlated with anticommons problems. In this respect, identifying large positive externalities from an innovation does not necessarily justify strong IP rights.

In summary, what Heller and Eisenberg (1998: 701) said about biomedical patent expansion generalizes to other forms of IP inflation: "It promises to spur private investment but risks creating a tragedy of the anticommons through a proliferation of fragmented and overlapping intellectual property rights." This causes people to "underuse scarce resources" (Heller & Eisenberg, 1998, p. 698). If left unchecked, the intended cure for a lack of incentives for innovation, IP, may actually end up "stifling creativity" (Vaidhyanathan, 2001, p. 185).

3.2 Political incentives and rent-seeking

The duration, scope, and stringency of intellectual property rights are set via endogenous political decisions. We therefore need to consider the institutional rules and incentives that shape political decisions. The optimal amount of IP protection may vary depending on the industry and the type of innovative process involved. However, once legislators set IP policy, it applies across a wide range of contexts. The "one size fits all" approach of IP makes it difficult to optimize it against complex, situation-specific, mutable tradeoffs (Shughart & Thomas, 2016, p. 171).

The history of copyright legislation reveals that even theoretically well-optimized rules can be undermined by regulatory capture and rent-seeking. In the United States, legislation has substantially increased copyright terms over time (Dourado & Tabarrok, 2015, p. 133). The sheer length of the IP extensions and their retroactive application to past works are hard to justify from an efficiency point of view. This suggests that rent-seeking efforts have prevailed over good faith attempts to create efficient policies that internalize externalities. One example is The Walt Disney Company, which successfully lobbied for the previously mentioned copyright term extensions, partially to stave off the entry of their iconic characters into the public domain (Dourado & Tabarrok, 2015, p. 134) despite the fact that "Disney's great genius, his spark of creativity, was built upon the work of others" (Lessig, 2004, pp. 22–23).

While legislators determine formal policies, these policies are implemented by bureaucrats and interpreted by judges. Legal practices vary across courts which encourages venue shopping by litigants. Some courts are especially receptive to "lawsuits filed by so-called patent trolls or 'non-performing entities' (NPEs)" (Shughart & Thomas, 2016, p. 179; Watkins, 2013). This generates negative externalities, even if the social costs of patent trolls are sometimes overstated (Haber & Lamoreaux, 2021) and even if people can find adaptive ways of working around them (see Sect. 4.2). As Martin (2013, p. 34) puts it, "[p]atent trolling acts as an unpredictable tax on other economic activity." To give another example, U.S. patent law since 1982 has "consolidated appellate review" into a special federal court endowed with "near-monopoly over patent appeals" (Dourado & Tabarrok, 2015, p. 135). Patent attorneys directly called for this change (Dourado & Tabarrok, 2015, p. 135; Landes & Posner, 2004, p. 27). This led to a substantial shift towards rulings in favor of patent holders (Henry & Turner, 2006). Increasing legal "specialization yields the old problem of capture: the fox guarding the chicken coop" (Landry, 1994, p. 1207).

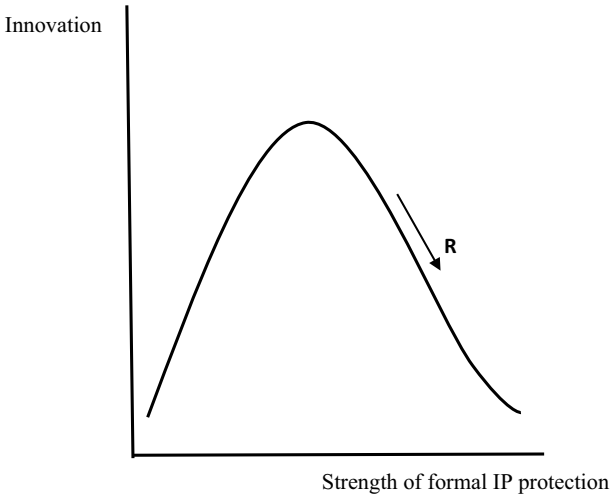

Fig. 2 Rent-seeking (R) pushes the supply of IP provision beyond the optimum

Globally speaking, U.S. diplomatic pressure and industrial rent-seeking have shaped international trade agreements on IP, such as the 1994 TRIPS agreement (Drahos, 1996; Dourado & Tabarrok, 2015, pp. 148–149; Devereaux et al., 2006; Stiglitz, 2008, p. 1694). TRIPS reinforced the global uniformity of IP law by making "trade sanctions a generally acceptable response against countries that fail to enforce a certain set of IP laws, eliminating a great deal of institutional diversity" (Martin, 2015, p. 86). Rent-seeking, nationally and globally, gave rise to a one-size fits all system that exacerbates the negative institutional externalities of IP. Absent institutional diversity, a single point of failure can lead to system-level harm.

Once we factor in the institutional constraints that shape the incentives faced by policymakers and lawyers, the best estimate is that the current level of IP protection either lies beyond the social optimum or tends in that direction. This is illustrated in Fig. 2 by the vector R, which denotes rent-seeking that pushes in the direction of excessive IP protection.

4 Polycentric self-governance and institutional diversity

The preceding analysis has highlighted the pros and cons of IP legislation as a remedy to externalities. IP rights internalize some externalities but also create new ones. Centralized IP legislation can often be effectively enforced over a large territory, which can create economies of scale, expansion of markets, streamlining of administration, and better adherence to the rule of law. However, centralization also means that *suboptimal* IP legislation can spread far and wide. Even in the presence of democratic accountability and institutional safeguards, centralized IP regimes tend to face the tragedy of the anticommons and the problem of rent-seeking.

Even in the best case scenario, a one-size-fits-all rule is likely to have adverse consequences in some contexts. The size and nature of the externalities involved in knowledge production vary substantially across institutional and social contexts. Many discussions of innovation and knowledge creation assume that knowledge is inherently a public good (Samuelson 1954; Nelson, 1959; Arrow, 1962). However, the nature of a good should not

be considered inherent to the good, but instead treated as contingent upon the institutional context within which it is consumed and produced (Cowen, 1985; Adams & McCormick, 1987; Coyne and Goodman, 2020). Treating knowledge as a public good with potentially large positive externalities suggests the *prima facie* viability of Pigouvian and Coasean solutions. Such remedies have context-sensitive usefulness. However, the nature of knowledge is more Protean. For example, as we explain further in Sect. 5.2, scientific knowledge may best be understood as a "contribution good… whose benefits are non-rival over contributors but that cannot be accessed by non-contributors." (Kealey & Ricketts, 2014, p. 1015).[4]

If knowledge is not always a public good, then different incentives may surround knowledge's positive externalities than those that are typically used to justify intellectual property. This is compatible with both recognizing some value in the traditional approach to externalities and in remaining agnostic about the optimal institutional mix between state-driven, market-driven, and community-driven alternatives in each context. Because the nature of the good, and therefore the incentives surrounding its production and use, vary across industries, countries, and contexts, there is value in pursuing institutional diversity rather than one-size-fits-all approaches. A substantial literature analyzes the concepts of "institutional diversity" and "polycentricity" (Carlisle & Gruby, 2019; Ostrom et al., 1973; Ostrom and Whitaker, 1974; Ostrom, 1990, 1996, 2005, 2010, 2012). This framework suggests that individuals and communities acting from the bottom-up often devise creative ways of addressing complex externality problems. People should be seen as *coproducers* (Ostrom, 1996), not only of the goods and services (or ideas) that they consume, but of the norms, rules, and institutions under which they operate.

A system is polycentric if it is characterized by "many centers of decision-making that are formally independent of each other" (V. Ostrom et al., 1961, p. 831). Competition and cooperation within polycentric systems result in "patterns of organization … [that] will be self-generating or self-organizing" (V.Ostrom, 1972, in McGinnis, 1999, p. 60). Ostrom's (1990, 2010) work on natural resource commons demonstrated that the long-term productive use of a resource frequently depends on a polycentric institutional approach that takes advantage of locally adapted norms and knowledge: "communities of individuals have relied on institutions resembling neither the state nor the market to govern [the commons] with reasonable degrees of success over long periods of time" (Ostrom, 1990, p. 1).

The processes of generating knowledge, making it useful, and cultivating *self-governing knowledge communities* exhibit features of polycentric institutional diversity. The appropriate framework, here, is that of the *knowledge commons* (Ostrom, 1990; Lessig, 2001, 2004; Strandburg et al., 2006; Hess & Ostrom, 2007; Strandburg, 2008; Madison et al., 2010; Dekker & Kuchař, 2022). Knowledge commons involve interaction between formal and informal rules, creative agents, and innovation networks. Research on the knowledge commons highlights the importance of "routines, conventions, and shared pool of knowledge" that together constitute "social infrastructures that may facilitate and hamper markets(,) create shared understandings, facilitate trust and, more generally, transform transaction costs to facilitate exchanges" (Dekker & Kucheř, 2022, p. 2). In the broadest sense, this gives rise to "cultures" (Mokyr, 2009, 2016) and "rhetorics" (McCloskey, 2010) of innovation.

[4] A "contribution good" resembles a club good (Buchanan 1965) in that it is non-rival but excludable. Kealey and Ricketts (2014, pp. 1015-1016) discuss the relation between these concepts.

The *Governing Knowledge Commons* (GKC) framework builds on the Ostromian Institutional Analysis and Development (IAD) framework, but "the IAD framework must be modified and extended to account for the wide variety of knowledge commons" (Frischmann et al., 2014, p. 16). One important difference between natural resource commons and knowledge commons is that "knowledge commons arrangements usually must create a governance structure within which participants not only share existing resources but also engage in producing those resources and, indeed, in determining their character" (Frischmann et al., 2014, p. 16). The creativity, adaptability, and rule-sensitivity of the user is also emphasized in the adjacent research field of the "innovation commons" which partially overlaps with the Ostromian framework (Allen & Potts, 2016; Potts, 2019; Potts et al., 2021). Coproduction of the knowledge commons is sometimes referred to as "user innovation" (Strandburg, 2008; von Hippel, 2005, 2017). Knowledge commons are therefore arenas of knowledge sharing and knowledge production taking advantage of "relationships between commons and other, related institutions" (Frischmann et al., 2014, p. 17). Moreover, "the nonrivalry of knowledge and information often rides on top of various rivalrous inputs (such as time or money) and may provide a foundation for various rivalrous outputs (such as money or fame)" (Frischmann et al., 2014, p. 17). Each of these issues can give rise to a variety of social dilemmas, and the GKC framework provides an analytical approach for analyzing how individuals try to solve them in diverse institutional contexts.

This framework demonstrates that individuals and communities partaking in the coproduction of the norms and rules of the knowledge commons can often generate their own set of diverse bottom-up solutions to the problem of complex externalities. Such creative solutions are "meso" level coordination devices that mediate between the "micro" level of the agent and the "macro" level of the economy (Dopfer et al., 2004, p. 267). Such polycentric mechanisms can act as bottom-up substitutes and complements to the formal IP regime and its traditional top-down alternatives, such as schemes of compulsory licensing, innovation prizes, and the *fair use* doctrine (Posner, 2005, p. 63; Slobodian, 2020, p. 80).

Our present analysis has proceeded on the assumption that the Pigouvian-Coasean economic story about externalities, market failures, and government failures is a good starting point for analysis that can be expanded with new tools and insights. To the extent that the GKC framework better explains knowledge production and dissemination, we have reasons to modify our understanding of the traditional remedies offered as optimal spurs for innovation. For example, if collaborative and user-led "free innovation" becomes the prime driver of innovation, the "devil's bargain" of IP rights needs to be renegotiated in the direction of "much less protection" (von Hippel, 2017, p. 148). However, as long as the collaborative knowledge economy encounters complex externality problems, the standard account remains relevant. Furthermore, the IP regime seems institutionally sticky in many industrialized countries. Whether or not it makes a net positive contribution to social welfare, we need to inquire what can be done to mitigate its negative effects through a pluralistic mix of private and community governance solutions (Dekker & Kuchař, forthcoming). The purpose of the analysis is to highlight the importance of institutional diversity as means of adaptively responding to the complex governance dilemmas of the knowledge economy. Whether market or community governance mechanisms are more efficient in each context is a secondary question that we do not attempt to settle here, although we explore some examples below.

In the following, we will explore some ways in which the informal rules, norms, and private governance structures that underpin the knowledge economy—e.g. social reputation, patent pools, and creative commons—can internalize the externalities of innovation,

potentially including both the positive market externalities of innovation *and* the negative institutional externalities caused by the IP regime itself. In this process, citizens as social entrepreneurs, creative agents, and coproducers of knowledge and norms, play an active, dynamic, "ecological" role (Smith, 2008, pp. 36–41). To illustrate this, we draw upon case studies developed by scholars using the GKC framework, as well as other researchers studying polycentric knowledge production. Researchers using the GKC framework emphasize the background conditions shaping the knowledge commons (including exogenous legal rules such as intellectual property rights), the features of the commons in question, and the governance arrangements that are developed (Frischmann et al., 2014). This charts the diversity of institutional arrangements involved in knowledge production and sharing. The polycentric institutional regime must take both formal and informal mechanisms into account in order to improve its net effectiveness, sustainability, and legitimacy. However, informal rules, just like formal rules, can be innovation enhancing, innovation dampening, or neutral in their effects. There are no "panaceas" in formal or informal governance (Ostrom et al., 2007).

4.1 Internalizing positive externalities using private and community governance

While formal IP rights offer one way to internalize externalities where knowledge production takes on the nature of a public good, "for many firms and industries, other means of appropriating returns to innovative activities, such as secrecy, lead time over imitators, confidentiality agreements, complexity, or learning by doing are preferred in practice" (Shughart & Thomas, 2016, pp. 183–184; see also Hall et al., 2014). Informal means of exclusion take various, sometimes surprising forms. Leeson (2016) argues that the Azande people used superstition to protect exclusive rights to otherwise replicable innovations. The discovery of medicinal benefits from tree bark may be easily replicated. If the innovator couples this remedy with a magic ritual, and claims that the remedy will be harmful absent this magic, then believers have incentives not to attempt to replicate the remedy. Superstition enables exclusion, and rewards for innovation, in the absence of legal enforcement. Other available mechanisms include bundling one's creative work with another more excludable and thus more profitable good (Shughart & Thomas, 2016, p. 185). For instance, touring musicians sell concert tickets, merchandise, and VIP meet-and-greets. Similarly, crowdfunding platforms like Kickstarter and Patreon allow for excludability and adaptive, context-specific "variation in the compensation to inventors" (Shughart & Thomas, 2016, p. 186).

The mechanisms discussed thus far are forms of private governance, in which entrepreneurs establish private organizations such as firms or clubs that then deliberately establish formal governance mechanisms. However, governance that internalizes externalities can also emerge informally at the community level (see Dekker and Kuchař, forthcoming). This community governance will often not be deliberately designed by entrepreneurs, managers, or others establishing formal rules. Instead, norms emerge through interactions among individuals. These norms are not consciously designed, but instead are emergent results of discourses, interactions, exchanges, and collaborations among members of a community.

Actions that are valorized under a community's norms will tend to result in private benefits for reputable individuals. For example, although many "open source" contributors do not initially get paid for their creative efforts, they can make money by "commercializing the name-brand capital signaled by their creative activities" (Shughart & Thomas, 2016,

pp. 185–186). Indeed, reputation has long provided an incentive for creative and innovative work. Reputation is often a sufficient reward in itself, since many people get satisfaction from social status and recognition. But it can also be cultivated instrumentally for financial gain, as a good reputation can open up lucrative opportunities. Scientific communities use similar reputation mechanisms (Mokyr, 2016), as we shall discuss at length later.

The aforementioned mechanisms—informal protections, the bundling of goods, crowdfunding platforms, and reputation—are just a few of the informal mechanisms available for internalizing the positive externalities of creative work. We are not claiming that such mechanisms are always present, or sufficiently strong on their own, to match (or surpass) the incentives for innovation offered by formal IP protection. However, it is clear that formal IP rights are not always the best means of internalizing the positive externalities of creative and innovative work. Nor is market governance always the best alternative to state action. Community governance may be required to solve particular governance problems.

4.2 Contracting around the tragedy of the anticommons

In a world of positive transaction costs, the proliferation of intellectual property rights can substantially raise the costs of engaging in innovative or creative work that builds on prior work. However, the existence of positive transaction costs need not mean "that individuals are forever trapped in a remorseless tragedy" (Ostrom, 2010, p. 322). Just as individuals can come together to govern common-pool resources, they can come together and contract with one another to alleviate the problems of the anticommons.

One way to alleviate this issue is using "patent pools." A patent pool occurs when a group of firms form a contract with one another to license their respective patents to each other. This can help reduce the costs of litigation among the firms, and it can create conditions where overlapping patents that would otherwise block one another or block innovation no longer have these adverse effects. Indeed, "the degree of internalization of the externalities of innovation that technology trading and licensing permits may contribute substantially to economic efficiency" (Baumol, 2001, p. 736). However, patent pool arrangements could also be used as a collusive agreement, enabling firms to combine their respective monopoly privileges and enforce a cartel strategy. In such circumstances, antitrust law promises to increase social welfare. If antitrust law restricts patent pooling too much, however, it may impede contractual solutions to anticommons dilemmas, thereby exacerbating the negative externalities of the patent system (Baumol, 2001; Carlson, 1999; Choi, 2010; Gilbert, 2004; Shapiro, 2001).

Another popular contractual device for alleviating the adverse effects of copyright is *Creative Commons* (CC) licensing. (See Sect. 5.1 below.) Wikipedia is an example of a non-profit that has successfully built its platform on such licenses (Dourado & Tabarrok, 2015, p. 144). Such licenses, once they are accepted as widespread substitutes for regular copyright licenses, lower the transaction costs associated with developing derivative works and thereby proactively mitigate the development of IP-related anticommons problems. Such contractual remedies are forms of private governance through which individuals and organizations contract with one another in order to modify the default legal rules established by the state. However, deliberate private governance then creates space for spontaneous community governance from the bottom-up as individuals interact informally within the knowledge commons.

Figure 3 illustrates the processes described throughout Sect. 4. The two curves illustrate how ignoring informal mechanisms of internalizing externalities may lead analysts

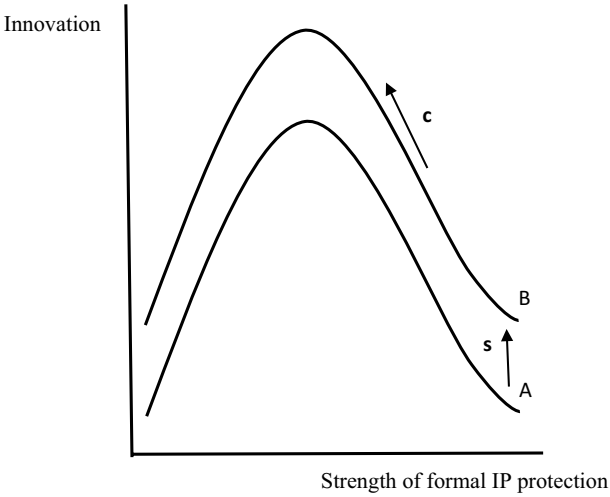

Fig. 3 Informal arrangements can both shift (**s**) the curve and create movement (**c**) along it. The *expected net consequences* are in the direction of increased innovation

to understate the levels of innovation (indicated by curve A) expected at any given level of formal IP protection. When informal mechanisms, utilizing both market and community governance types, are available to internalize externalities, more innovation will occur regardless of the level of formal IP protection, and therefore the curve will be higher than otherwise expected, indicated as a *shift* (**s**) of the curve from A to B. The vector **c**, by contrast, illustrates how *contracting and pooling* of the type discussed in Sect. 4.2 can move the world closer to the peak of the curve, away from an excessively strong IP regime. Although the *direction* of each arrow is generally predicted to point in the direction of increased innovation (*ceteris paribus*), their *magnitude* depends on context-specific, empirical factors.

5 Case studies of the knowledge commons

To illustrate the variety of bottom-up governance mechanisms used to address diverse externality issues, it is useful to look in more detail at specific industries and institutional contexts. We consider two cases: the open source software (OSS) industry (Lessig, 2001, 2004; Raymond, 1999; Schweik, 2014; Schweik & English, 2012; Stallman, 2006) and the scientific community (Kealey, 1996; Kealey & Ricketts, 2014; Mokyr, 2016).

5.1 Open source software

In 1980, changes to copyright law in the United States allowed for more stringent IP protections for software (Schweik, 2014, pp. 255–256). Fearing that this threatened opportunities for collaboration, knowledge sharing, and iterative innovation among software developers, Richard Stallman and others in the "free software" movement devised ways to contract around potential anticommons problems and other negative externalities of IP: "Stallman's major innovation was … his brilliant use of copyright law to create software licenses, such as his General Public License (GPL) for software (…), that promote sharing and collaboration" (Schweik, 2014, p. 256).

These licenses worked within IP law to create a set of legal and informal institutions in which software became open for sharing, collaborative use, and iterative innovation. Due to their openness, "OSS licenses have the potential to generate a large community of users and developers—larger than any one proprietary organization could create—to develop, test, and debug future versions of the software" (Schweik & English, 2012, p. 6). This is a good example of the significant contribution that "user innovators" (von Hippel, 2017) can make to solving a crowdsourced problem: "Given a large enough beta tester and co-developer base, almost every problem will be characterized quickly and the fix obvious to someone" (Raymond, 1999, p. 30). The importance of "user innovation" for consumer welfare has also been observed in adjacent fields like video game hobbyism (Abrate & Menozzi, 2020; Koch & Artmayr, 2019).

However, making the software open to duplication and use raises the question of what incentivizes developers to contribute to the production of new software. As we discussed in Sect. 4.1, reputation provides one such incentive. Another relevant incentive to contribute may arise from the desire to develop or improve software for one's own use. User innovation is a type of coproduction in which end users of a product or service directly contribute to the innovation that improves that product (von Hippel, 2005, 2017). Research examining the OSS projects hosted on SourceForge.net (SF) shows "that user need is a major motivation both for individuals to participate and for their employers to encourage them to participate (because the employing organization needs the software)" (Schweik, 2014, p. 264). Additional motivations to contribute include "the desire to learn and improve skills through reading the code and interacting with other OSS developers…and, for some, a philosophical commitment to the idea of OSS" (Sen et al., 2022, p. 65).

Creating a successful OSS project requires opportunities for collaboration in addition to appropriate individual incentives. Success often depends on "finding 'just the right person' with similar interests, skills, and passions somewhere in the world and developing a collaborative relationship with that person," with the help of websites such as SF and Google (Schweik, 2014, p. 265). Schweik (2014, p. 265) explains that surveying SF projects found that "52 percent of the successful growth-stage projects had development team members from multiple continents."

Economists often recommend formal institutions to internalize externalities. Yet programmers often find formal institutions stifling, because they "want to program, not to deal with rules guiding collaboration" (Schweik, 2014, p. 266). Schweik (2014, p. 266) finds that in "most of the SF projects [they] surveyed, the operational rules are either 'very informal' social norms or are coded into the online collaborative system (…). We did not find many formal operational rules that were socially enforced." This does not mean that formal rules are altogether absent. As teams become larger, some formalization occurs. However, there are serious tradeoffs associated with the use of formal institutions in this context.

To supplement small and informally organized teams, larger organizations "have emerged as second-order actors in the production of OSS. They provide various collective services to aid OSS projects, such as legal, technical, and financial support" (Sen et al., 2022, p. 65). Often these are nonprofit organizations. Today, over 100 nonprofits exist in the OSS sector alone (Sen et al., 2022, p. 65). One such nonprofit is the Apache Software Foundation (ASF) incubator that "is likely aiding in the sustainability of the commons" by providing OSS "projects with skills and resources they need but do not possess." (Sen et al., 2022, p. 73) This illustrates the capacity of a polycentric system that features nested organizations at multiple scales to help to internalize the complex externalities of the knowledge economy that are insufficiently solved by the formal institutions. Moreover,

it illustrates how specific conditions of the OSS industry, such as the nature of the good produced and the norms and values of programmers, shape which types of institutional solutions are well-suited to addressing its externalities.

The OSS movement illustrates the complex relationships between private governance and community governance. Stallman and others created CC licenses to contract around the state's strong IP rules. This private entrepreneurship then created space for collaboration among developers and users. Within this space, community governance emerges, and developers often prefer the community's informal norms to privately established formal rules. However, private firms and nonprofit organizations can establish complementary formal private governance in some parts of the OSS sector. This nested relationship between private and community governance enables a diversity of institutional solutions to address different types of social dilemmas.

5.2 Scientific communities

The OSS community directly produces software for use by consumers. This creates conditions for user innovation, as discussed in the previous section. Other types of knowledge production, however, face different conditions. For instance, the production of scientific knowledge is often not directly tied to the production of any specific product or service. Sometimes it is tied to technological innovation, which does reach consumers, but scientific discovery in general is an earlier stage of production than consumer-facing innovation. The production of scientific knowledge, therefore, involves a different context and different dilemmas than OSS. In this section, we analyze self-governing institutions that encourage scientific discovery and innovation.

Mokyr (2016) argues that the emergence of the "Republic of Letters," an international community of scientists and innovators, was a significant contributor to the Industrial Revolution. Participants in this community did not primarily use IP or other formal mechanisms to keep the returns from their discoveries private. Instead, they shared them openly and benefited from using such discoveries to build their individual reputations. As Mokyr (2016, p. 183) explains:

> "The growth of open science as the central institutional principle of the intellectual world of early modern Europe… was an emergent property, the unintended consequence of a different phenomenon: scholars trying to build reputations among their peers."

Contrary to the claim that the patent system was the key driver of the Industrial Revolution (Spulber, 2021), the Republic of Letters framework suggests that other institutions, including informal ones, "may have been equally important or more so than the patent office" for generating technological growth, even if "the patent system had on balance a positive effect on technological progress" (Mokyr, 2009, p. 349).

As previously noted, scientific knowledge has aspects of a "contribution good" (Kealey & Ricketts, 2014, 2022). In order to replicate a piece of scientific knowledge one must acquire relevant tacit knowledge by contributing to science oneself. Because noncontributors are effectively excluded from the pool of potential beneficiaries, exclusion mechanisms are less useful than they might be in other contexts. Instead, the relevant dilemma is a coordination problem associated with reaching critical mass. "The main fear on the part of participants is not that their ideas will be picked up and used by others, but that other potential contributors will not have the confidence to engage and will underestimate the

private advantages that access to the collective resource will bring" (Kealey & Ricketts, 2022, p. 26). The punishment and exclusion rules of scientific research societies appear more consistent with solving this type of coordination problem than addressing concerns associated with public goods or common-pool resources. This is shown by the fact that numerous scientific and engineering research associations proliferated across Britain in the leadup to the Industrial Revolution (Kealey & Ricketts, 2022).

A complementary account is offered by Ridley (2020), who argues that innovation, at least since the First Industrial Revolution, is best understood as a property of *collaborative networks,* composed of fortuitously placed garage tinkerers, artisans, and other user innovators, rather than isolated geniuses and patent holders like Edison and Franklin. The growth of knowledge thrives in a permissive and competitive institutional environment that supports the free and open exchange of habits, norms, and ideas. As Hayek (2011, p. 97) put it: "It is through this free gift of the knowledge acquired by the experiments of some members of society that general progress is made possible, that the achievements of those who have gone before facilitate the advance of those who follow." The process of cumulative innovation may be undermined by excessive "patents of monopoly" that make "the uses of new knowledge (…) artificially scarce" (Hayek, 2011, p. 97). To curtail this, some GKC scholars recommend increased legal protection of the rights of citizens "to innovate collaboratively and to diffuse information about their innovations to others openly" (von Hippel, 2017, p. 128). More work needs to be done to ascertain what kind of IP regime, if any, is compatible with such widespread "rights to innovate" (von Hippel, 2017, p. 127; Lehto, 2022).

6 Conclusion

Given the importance of innovation and knowledge to economic growth and consumer welfare, incentives for innovation are important. The state can help internalize the positive externalities of innovation as a guarantor of the legal framework of property, contract, and exchange, and as a regulator of externalities and public goods. However, state-enforced IP rights are only one (and not necessarily the best) means of promoting and shaping the innovation economy. Although it may be true, as Haber & Lamoreaux (2021, p. 23) argue, that "[f]or all their imperfections, US-style patent systems spread because they had multiple advantages," the advantages of formal IP instruments (including patents, copyrights, and trademarks) must be measured against their institutional complements and substitutes. This includes not only alternative top-down mechanisms of governance, like state-funded prizes, grants, and innovation subsidies, but also various bottom-up mechanisms of polycentric self-governance.

The knowledge economy is best conceptualized as involving the multi-level, nested co-production, co-governance, and co-consumption of ideas, innovations, and social norms by millions of interacting agents. In this framework, top-down IP rights may have a potential role in advancing the innovation capacity of the economy by internalizing the externalities caused by, and filling in for the lacunae left by, self-governing communities of creativity and discovery. However, in many industries and contexts, a high degree of incentive compatibility between the private and public returns on innovative and creative activity may be better achieved by relying more on a polycentric mixture of community self-governance and private governance mechanisms.

Moreover, in a world with significant transaction costs, the political assignment of too many overlapping property rights can generate a tragedy of the anticommons as well as rent-seeking opportunities. Together, these can prevent IP from optimally internalizing the complex externalities of innovation. Fortunately, institutional diversity can generate and accommodate various institutional substitutes and complements to the formal IP regime that can mitigate these problems through both private and community governance mechanisms. In creative and dynamic ways, self-regulating and interacting individuals, clubs, networks, communities, universities, and businesses can govern themselves in ways that do not inexorably lead to either "market failure" or "government failure." Polycentric institutions, although subject to their own errors and failures, play a crucial role in, and often succeed in, internalizing (or changing the magnitude and direction of) the complex positive and negative externalities of the knowledge economy, thus shaping its evolving system of rewards and punishments towards increased (if imperfect) incentive compatibility.

The formal and informal mechanisms involved in the multi-level, polycentric internalization of complex externalities in the knowledge economy may well include monocentric copyright and patent protections. At the same time, an excessive degree of formal IP protection may be counterproductive to the goal of advancing innovation. IP rights necessarily impose social costs as well as confer social benefits. Discovering the optimal stringency, scope, and duration of formal IP protection requires recognizing the importance of institutional diversity in internalizing complex internalities. Our analysis has remained largely neutral in the debates about the "real" nature of knowledge as a good (private, public, or something else), and whether the knowledge economy of the coming decades is more suited to market based solutions or community self-governance solutions. Regardless of the answers to those questions, we have highlighted the importance of institutional diversity in reducing the transaction costs and mitigating the externalities of a largely monocentric IP system. Important theoretical issues and empirical facts are still waiting to be settled about which polycentric institutional arrangements are best suited to which industries, places, and contexts. This calls for a careful, contextual analysis of *all* the types and tokens of IP against *all* their (formal and informal) institutional substitutes and complements. In this task, the further empirical and theoretical study of the knowledge commons should play a crucial role.

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