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Promoting systemic collaboration for sustainable innovation through intellectual property rights

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ABSTRACT

Sustainability transitions call for new forms of collaboration supported by proper regulatory structures that enable multiple actors across sectoral boundaries to contribute to a system-level change towards more sustainable production and consumption practices. This paper integrates innovation research with intellectual property law to explore how such a systemic collaboration for sustainable innovation should be characterised, and how the intellectual property rights (IPR) system could be shaped to support it. First, we analyse existing research on open innovation and IPR and point to limitations in their applicability to systemic transitions for sustainability. Second, drawing on innovation ecosystems research, we outline a model of systemic collaboration for sustainable innovation, which highlights the co-specialisation of heterogeneous actors around system-specific alignment structures as the basis of the creation of system-level sustainability-improving solutions. Third, we analyse the limitations of the current IPR system vis-à-vis this type of systemic collaboration model and develop novel insights into how IPR could be shaped and leveraged to support systemic sustainable innovation.

1. Introduction

Research is increasingly pointing to the need for the private, public and third sectors to innovate more sustainable production and consumption practices (e.g., UNEP, 2011) to tackle the urgent ecological crisis (e.g., IPCC, 2018, 2021; Ripple et al., 2017). The challenge with innovation for sustainability is that sustainability impact arises from multi-layered interactions among individual and organisational actions, technological developments, institutional and regulatory factors, natural processes, and so on, *at a systemic level* (Bansal & Song, 2017; Ferraro et al., 2015; Rip & Kemp, 1998). Indeed, as also highlighted by several policy measures, such as the United Nations Sustainable Development Goals 2030 (specifically SDG 17: partnerships for sustainable development), multi-stakeholder collaboration in innovation is needed in order to accomplish "strong" sustainability that challenges existing structures of production and consumption to fit industrial activities within the capacity of the Planet (Roome, 2012).

In this context, important questions pertain to finding ways for inducing collaborative innovation activities among actors and supporting these activities through appropriate intellectual property rights (IPR) frameworks. These issues are explored in research on open innovation (OI), which focuses on different models of collaborative innovation and how IPR tools are utilized to enable these activities (e.g., Bogers & West, 2012; Chesbrough, 2003; Van Overwalle, 2015). While discussing ways to support collaborative innovation, existing OI models also come with limitations when considered in the context of sustainability and the need for novel, system-level solutions. For instance, the existing OI models based around focal firms or user communities can limit the scope of innovation activities vis-à-vis sustainability targets and prevent contributing actors from achieving cumulative developments necessary for a system-wide transitions (e.g., Tietze et al., 2017). Thus, new forms of collaboration, and new IPR frameworks to support them, are needed to allow multiple actors across sectoral boundaries to contribute to both short-term innovation activities and long-term reconfiguration of wider socio-technical systems (Adams et al., 2016; Markard et al., 2012; McMeekin et al., 2019; Quist & Tukker, 2013).

In this paper, we extend previous discussions around OI and IPR by proposing a model of *systemic collaboration for sustainable innovation* and exploring how IPR can limit and support such collaboration. Drawing on the literature on innovation ecosystems (e.g., Adner, 2017; Jacobides et al., 2018; Thomas & Autio, 2020), this model extends previous OI

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research by focusing on non-hierarchical collaborative arrangements through which heterogeneous actors combine their complementary resources for the creation of novel, sustainability-improving solutions at a systemic level. The innovation ecosystems research draws particular attention to the distinct logic with which ecosystems coordinate and govern collaborative knowledge-building and innovation activities, as well as create and capture economic value. In this paper, we suggest that this form of collaboration can also provide new ways forward with the development of sustainability-improving solutions by shedding light on the dynamics that allow different types of actors to contribute to the development of sustainability-improving solutions that are characteristically systemic in nature (e.g., Aarikka-Stenroos et al., 2021).

To support systemic collaboration for sustainable innovation, IPR play a critical role. On the one hand, IPR incentivise innovations by creating a temporary and relative monopoly-like set of rights for innovators. As such, IPR can facilitate collaboration and knowledge exchange through, for example, knowledge codification and reduction of uncertainty (Gans et al., 2008; Hertzfeld et al., 2006). At the same time, however, research suggests that the role of IPR in OI is somewhat paradoxical as IPR might also limit systemic collaboration for sustainable innovation (Tietze et al., 2017). Partly this is related to the way that currently existing OI models are built, while partly it is also a characteristic of the IPR system per se. For example, the use of existing IPR tools can create conflicts over IPR sharing or value appropriation, limit sequential innovation, and slow down the transfer and diffusion of innovations required for achieving the systemic sustainability impact (Alexy et al., 2009; Andersen & Konzelmann, 2008; Brüggemann et al., 2016; Henry & Stiglitz, 2010; Thambisetty et al., 2021; Yu et al., 2017). Therefore, for IPR to properly support systemic collaboration for innovation, new ways to navigate this paradox need to be created.

Against this backdrop, the purpose of this paper is to extend understanding on the role of systemic collaboration for sustainable innovation, as well as the requirements that this collaboration creates for reshaping the IPR system and IPR mechanisms available to organizations. Specifically, the paper integrates innovation research with intellectual property law to 1) shed light over the existing OI models and the (old and new) role of IPR in these models; 2) develop a model of systemic collaboration for sustainable innovation and argue for its importance for promoting the needed systemic change; and 3) explore the limitations of the current IPR system and how IPR could be reshaped to promote systemic collaboration for sustainable innovation.

The contributions of this paper are two-fold. First, based on an analysis of existing OI models and the role of IPR in supporting them, the paper proposes the model of systemic collaboration for sustainable innovation as extension to OI research with specific focus on sustainable innovation. The proposed model emphasizes multi-actor collaboration which, through co-specialization and shared alignment structures, enable actors to direct their innovation efforts around a shared, sustainability-improving solution at a systemic level. Second, the paper reflects on the essential role that IPR play in limiting and supporting systemic collaboration for sustainable innovation. Specifically, the paper identifies several ways in which the current IPR system limits systemic collaboration and reflects on changes needed both in its fundamental justifications and licensing structures. These insights pave way for a deeper understanding of the role of IPR in supporting systemic collaboration for sustainable innovation, thus extending present discussions around IPR to consider the changes needed to support the collective efforts to find solutions to sustainability challenges.

2. Open innovation: existing concepts and IPR structures

To ground the discussion on systemic collaboration for sustainable innovation, and the role of IPR in that context (which follows in Sections 3 and 4), this section develops an overview of the established models of OI and the role of IPR in collaborative innovation. In broad terms, OI accentuates the importance of both internal and external sources of ideas and knowledge for innovation, as well as utilisation of internal and external paths to market (Chesbrough, 2003, 2006). Several adjacent research streams have contributed to the growing volume of research on OI, distinguishing different levels of OI such as individuals, firms, inter-organisational networks and nations (Bogers & West, 2012; Gassmann et al., 2006; West et al., 2014). In this paper, we focus on two main comprehensive clusters, namely the firm-centric and user- or community-centric research streams.

The firm-centric view of OI is grounded in Chesbrough's work, which emphasises the use of external and internal ideas, as well as external and internal paths to market, as a basis of innovation (Chesbrough, 2003). As opposed to the "closed" innovation model, the firm-centric OI paradigm embraces the fact that not all relevant knowledge resides within the company, and that to benefit from an innovation, knowledge does not have to originate in the company's own R&D. Thus, with OI, companies do not compete based on internal R&D capability, but rather on business models that allow them to access innovative ideas from external sources, integrate them into innovation and core business processes inside the organisation, and commercialise them using internal and external paths to market (West & Bogers, 2014). In this model, firms leverage the ownership and selective licensing of IPR—most notably patents—as means for protecting and capturing value from innovation. For example, firms can use licensing to commercialise "non-core" technological innovations and engage suppliers and other partners in expansive innovation activity around new technologies (e.g., Masucci et al., 2020). As Van Overvalle (2015) explains, "[t]he role of patents in a context of knowledge creation and sharing is to identify and determine partners' contribution to the cooperation (so-called background rights), the achievements made within the cooperation (so-called foreground rights) and those made thereafter (so called follow-on rights)". The challenge with this model is, however, that it limits productive knowledge-sharing by emphasising profit maximisation from the perspective of the focal firm, along with strong appropriability based on tight control over IPR.

By contrast, research on IPR in user and community-centric OI has focused on various types of collective or user innovations (Allen, 1983; von Hippel, 1988). Several studies characterise the dynamics of this form of OI in innovation communities, such as open source software and open source hardware development communities, pointing out how such communities function to support innovation efforts by community members, as well as sharing innovations with and beyond community boundaries (Benkler, 2017; Franke & Shah, 2003; Henkel, 2006; van de Vrande et al., 2010). While both the firm-centric and user- and community-centric OI streams share an interest in distributed innovation spanning organisational boundaries, there are also clear differences (e.g., Bogers & Bekkers, & Granstrand, 2012; Bogers & West, 2012; Chesbrough & Bogers, 2014; Van Overwalle, 2015; West & Lakhani, 2008; West et al., 2014). Notably, user- and community-centric OI research focuses on collaborative innovation in communities outside the boundaries of focal firms, and is primarily based on non-pecuniary forms of innovation. Furthermore, user- and community-centric OI emphasises community rules and norms as the basis of voluntary contributions to innovation over hierarchical control.

In terms of IPR, user- and community-centric OI typically relies on copyrights, as well as to some extent on design rights, which are used through open source licensing schemes to freely (although in some cases conditionally) share innovations and distribute benefits among community members and users. Legally, the copyleft or open source licence model combines different individual licensing structures by entailing a non-exclusive blanket licence with a compulsory non-exclusive grant-back blanket licence. Sharing open source software and hardware related-innovations has been enabled by many different types of open source licences (e.g., FLOSS; CERN Open Hardware Licence) as the basis for rights clearance. Most of these licences allow people to easily give permission to others to use their IPR protected innovations. For example, FLOSS licenses in the software context enable copyright owners of the code to open up their IPR via open source software

licences that grant a royalty-free right to 'run, modify, distribute, and redistribute' modified versions of the computer program (Välimäki, 2005). The open source hardware initiatives work in a similar manner. Although these types of models are grounded on a paradigm of open IPR sharing, they are well-functioning when it comes to sharing copyright-protected works, but they suffer from several limitations when it comes to share other IPR, such as patents (Haapanen, 2017).

To explore the IPR questions linked to OI in more depth, previous literature has pointed out that the two pillars of OI are (Van Overwalle, 2015): (1) the pre-existence of IPR, that is, a public ordering tool, and (2) a contract / licence, that is, a private ordering tool. Notably, although both pillars are essential and must be carefully scrutinised in the context of OI, so far most of the attention has been given to the second pillar, namely the role of private ordering tools like contracts and licenses to enable OI. Indeed, it is undeniable that to spur OI and collaboration (in general, and towards sustainable innovation in particular), the effectiveness of the design of the IPR system in relation to the ease (e.g., level of transaction costs) with which right holders can enter into licensing and other contractual arrangements involving these rights is essential (Gallini & Scotchmer, 2002; Van Overwalle, 2015). At the same time, however, the way that we theoretically justify and thus structure IPR rules (first pillar) should also be in line with the goals of innovation. In other words, collaborative innovations for sustainability are not just a result of how IPR are used (e.g., licensed), but sustainability should also be a characteristic that is emphasized in the way the IPR themselves are justified and structured (Pihlajarinne and Ballardini, 2020). At the moment, this emphasis on sustainability in IPR is not sufficient, thus the current justifications and structures for the monopoly rights created by IPR might impose obstacles for collaboration and knowledge sharing (Reichman, 2000; von Hippel, 2005).

Indeed, all this is both a problem that directly derives from the way that existing OI models are built, as well as an issue of the IPR system as such. In the context of sustainable innovation, these existing structures might impede long-term collaboration to achieve system-level changes, such as solutions for the circular economy. For example, the pre-existence of IPR might block possibilities for (re-)using, (re-)making, (re-)manufacturing, repairing and refurbishing protected items or services unless permission is obtained from the right holder. It is not possible to overcome these limitations by only looking at the second pillar of OI (contract/licensing), but this ambition also requires us to (re-)align both the IPR justifications and structures with the characteristics and needs of innovation activities focused on sustainability-improving solutions at a system level. Before engaging in this discussion in more detail, however, it is important to elucidate the key features of systemic collaboration for sustainable innovation.

3. Systemic collaboration for sustainable innovation

Systemic change in the spirit of "strong" sustainability (Roome, 2012) calls for new forms and mechanisms of collaboration, supported by proper regulatory structures, that enable multiple actors across sectoral boundaries to contribute to both short-term innovation and long-term reconfiguration of wider socio-technical systems (Adams et al., 2016; Markard et al., 2012; McMeekin et al., 2019; Quist & Tukker, 2013). Thus, systemic change for sustainability creates new requirements on collaborative innovation activities that extend beyond current OI models and their use of IPR in at least three ways. First, systemic sustainability transitions call for the involvement of a diverse group of stakeholders from suppliers, customers and competitors to research institutions, non-profits and policy makers in the creation of new, system-level solutions to sustainability issues, expanding the scope of collaborative innovation beyond the current OI models. Second, the development of sustainability-improving system-level solutions require the balancing of economic, social and/or environmental objectives, which interact with the complex and path-dependent technological, scientific, economic, social, user/market, and political processes of wider socio-technical systems (Geels, 2004; Geels & Schot, 2007; Smith et al., 2010). As a result, issues in the coordination and governance of collaborative innovation become more complicated than in the firm- or community-centric OI models that are often based around specific technologies. Third, as systemic sustainability transitions are based on the reconfiguration of the structures of current socio-technical systems, including not only physical or technological architectures but also the social, economic and regulatory structures that bind actors together in an industry or market (Bolton & Hannon, 2016; Garud & Karnøe, 2003; Jacobides et al., 2006; McMeekin et al., 2019), the emphasis of collaborative innovation shifts from isolated technology development to developing and scaling up new and more sustainable ways of production and consumption at a system level.

To respond to these issues and enable a fuller discussion of the IPR issues relevant to systemic sustainable innovation, we propose a third model of collaborative innovation as extension to the previously discussed OI models, which we characterise as *systemic collaboration for sustainable innovation*. In detailing this model, we use as a backdrop the insights of sustainability transitions literature (e.g., Smith et al., 2005; Markard et al., 2012), and draw particularly on research on innovation ecosystems, which analyses new forms of collaboration that underpin the creation and implementation of system-level solutions through multi-actor collaboration (e.g., Adner, 2017; Gawer, 2014; Jacobides et al., 2018; Järvi et al., 2018; Nambisan et al., 2019; Thomas & Autio, 2020). While this literature has provided new insights into economic value creation and innovation in ecosystem arrangements, we argue that systemic collaborations can also provide valuable ways forward for developing sustainability-improving solutions because of the emphasis on solutions at the system level.

We identify three main characteristics for systemic collaboration for sustainable innovation. First, as pointed out above, systemic collaboration involves an array of heterogeneous, loosely connected actors in creation of a system-level output or solution (Thomas & Autio, 2020). For example, research on contemporary digital platform ecosystems highlights how a group of actors from different industries, linked through a shared technology platform, are needed to realise the system's value proposition for customers (Gawer, 2014; Jacobides et al., 2018). From the perspective of innovation collaboration, this sets specific requirements for coordinating and governing innovation-related activities (Adams et al., 2016; Bolton & Hannon, 2016; Smith et al., 2005) with focus on the co-creation of systemic solutions that are beyond the capabilities of any single ecosystem member (Adner, 2017). In the context of electric vehicles, for instance, systemic sustainability transition calls for the involvement of not only car manufacturers, but also of battery and electric drivetrain developers, charging station operators, car service companies, and regulators to achieve a shift to electric mobility at a system level (e.g., Bohnsack et al., 2014).

Second, systemic collaboration for sustainable innovation is based on the complementary assets and competencies of the heterogeneous actors involved. The challenge for systemic collaboration is that complementary assets need to be organised and coordinated in ways that enable specialised actors to contribute to the creation and delivery of system-level output in a mutually reinforcing manner. The process through which this happens is *actor co-specialisation*, which refers to the coevolution of system-specific interdependencies between actors (Thomas & Autio, 2020). Some complementary assets are generic in nature, that is, available to solution developers in existing markets (e.g., green electricity for production processes). However, as such complementarities pose no particular challenge to collaborative innovation in terms of coordination and alignment, they are of lesser interest here (Teece, 1986). Rather, actor co-specialisation becomes an essential question with non-generic complementarities, that is, complementarities that are specific to a novel system-level solution (Jacobides et al., 2018).

For example, a system of photovoltaic energy production requires solar panel manufacturers, racking producers and installation providers to develop specific complementarities between solution components (e.

g., how the panel fits the racking, how the racking connects to the roof) to enable design and delivery of a solar panel solution to customers. Furthermore, complementarities in relation to the energy grid (e.g., smart meters, feed tariffs) create conditions for scaling up such solutions in the context of the broader energy production system, enabling an industry-wide transition to decentralised energy production (McMeekin et al., 2019). The point here is that any one part of such a systemic solution does not function without specific types of complementarities between all parts. And developing such complementarities (specifically complementarities that increase the value of system-level output) requires co-specialisation among actors through which each contributor becomes more efficient and effective in developing and delivering their part of the system-level solution. This dynamic is central to systemic collaboration for sustainable innovation.

Third, actor co-specialisation and the development of (non-generic) complementarities require specific relational structures through which the actors align and coordinate mutual innovation and production activities vis-à-vis the system-level solution (Jacobides et al., 2018). While systemic collaboration for sustainable innovation can leverage both hierarchical and market-based governance structures in parts of the system-level solution, particular emphasis is placed on system-specific alignment structures that are based on sets of shared and accepted actor roles, and the flows between them, that link actors together (Adner, 2017; Thomas & Autio, 2020). For example, whereas the firm-centric OI model relies on detailed, relationship-specific contracts that define the scope and "rules" of collaboration, knowledge sharing and value appropriation (e.g., through exclusive licensing schemes with suppliers), systemic collaboration can leverage shared technological architectures, as in the case of digital platforms, and modular ecosystem organisation that is based around sets of mutually compatible roles, as the basis of collaboration (Adner, 2017; Gawer & Phillips, 2013; Jacobides et al., 2018).

A specific feature of this type of governance is that it allows the actors to coordinate their contributions to system-level output in a manner that is distributed and not fully hierarchical (Jacobides et al., 2018). That is, it provides a "hybrid" governance structure which retains the ability of the ecosystem members to make their own innovation and business decisions, while creating a basis for actors to contribute to the development and implementation of a system-level solution. To facilitate such hybrid governance, systemic collaboration for sustainable innovation places emphasis on opening at least some of the modules of the system-level solution for others to freely use and leverage to enable the coevolution of complementary assets for a system-level solution. At the same time, companies must also find ways to benefit financially from their innovation contributions in this new mode of collaborative innovation. For example, collaborators can selectively share parts of their solution with others while retaining ownership over parts central to their business model (e.g., Henkel, 2006). Or, as evident in digital platforms, opening certain modules of a system-level solution is coupled with efforts to maintain control over critical, system-defining assets, including the platform architecture and APIs, that enable platform leaders to shape the alignment structures that direct co-specialisation and control the contributions of complementary actors (Jacobides et al., 2006, 2018; Gawer & Cusumano, 2008).

As summarized in Table 1, the *systemic collaboration for sustainable innovation* model highlights a form of collaborative innovation in which heterogeneous actors collaborate in the realisation of a system-level, sustainability-improving solution. In contrast to the two existing OI models, systemic collaboration for sustainable innovation relies on the co-evolution of system-specific interdependencies between actors, or actor co-specialisation. This process is coordinated and governed by system-specific alignment structures, which direct co-specialisation through sets of modular roles that enable the actors to simultaneously direct their innovation efforts around a shared, sustainability-improving solution at a systemic level, while retaining autonomy for short-term innovation and business decisions. Furthermore, this process creates the basis for the emergence of novel system architectures, or ways of organising tasks to accomplish system-level objectives (Jacobides et al., 2006). As sustainability impact arises from changes in the system-level organisation of production and consumption activities (Adams et al., 2016; Ferraro et al., 2015; Rip & Kemp, 1998), systemic collaboration can play a central role in creating new and more sustainable models for value creation. Furthermore, once new ecosystems are created, they not only enable delivery of systemic solutions for sustainability, but also play a significant part in directing (and constraining) subsequent innovation within the alignment structures of the system (Garud & Karnøe, 2003).

As this new form of OI imposes complex and multi-dimensional demands on a system-level solution, as well as the actors themselves (Ferraro et al., 2015; Schad & Bansal, 2018), it challenges several of the current fundamentals of the IPR system, including its theoretical justifications and structures to support convergent and complementary innovation for systemic sustainability. In the next section, we will examine these issues in more detail.

4. IPR structures for systemic sustainable innovation

4.1. Current challenges and failed attempts

Because systemic collaboration for sustainable innovation relies on the development of complementary assets and competences among a group of heterogeneous actors involved in the creation of a system-level output, an adequate level of protection and usage of IPR is crucial both for unlocking innovation and for accelerating the scale-up of system-level solutions, thus facilitating sustainability transition on a broader scale. However, the existing IPR system suffers from some major shortcomings when we consider it from the perspective of systemic collaboration for sustainable innovation.

First, the theoretical justification that underpins the current IPR system relies quite strongly on the moral foundations of theories such as utilitarianism, but also labour and personality theories, that prioritise private and individual ownership, and economic profit maximisation

Table 1
Three models for collaborative sustainable innovation.

	Firm-centric	Community-centric	Systemic
Nature of innovation collaboration	Use of internal & external ideas as the basis of a firm's innovation projects. Use of internal and external paths to market to maximise profits from innovation.	Participation in and contribution to loose-knit innovation (e.g., open source) communities.	Multi-actor innovation ecosystems in which different types of actors collaborate to realise system-level solutions.
Intended outcome	Increased competitive advantage for the focal firm through (sustainable) innovation.	Creation and sharing of outputs that benefit all innovation participants (including financial, social, environmental benefits).	Creation of economic (private) and environmental (collective) outcomes.
Nature of "openness"	Restricted: Focal firm determines which ideas allowed to pass firm boundaries, which paths to market are used.	Broad: Inclusive communities that are easy to participate in; benefits accessible to all (conditional / non-conditional).	System-specific: Ecosystem participation by complementary actors that contribute to joint output based on shared roles and technologies.
Governance	Controlled by the focal firm: Collaboration restricted to a small number of partners, based on bilateral contracts, licensing arrangements.	Decentralised: Voluntary collectives based on loose "rules", shared norms and worldviews.	Hybrid: Guided by shared system-level output, directed by shared alignment structures which afford actor co-specialisation.

(Ballardini et al., 2021; Pihlajarinne and Ballardini, 2019). Although this theoretical basis does not exclude sustainability from the foundations of the IPR system, its application is not always in line with the systemic collaboration for sustainable innovation model, particularly in terms of the objectives of innovation (including economic as well as cultural, social and environmental dimensions of sustainability) and the need for reciprocity and collectiveness to enable co-specialization around shared technologies (Witoszek & Sorensen 2018). For instance, sustainability-oriented innovation is dependent not only on practices for sharing of IPR protected innovations and technologies, but also on activities that promote diversification of knowledge amongst actors and enable them to resolve conflicts of interest to sustain productive collaboration that leverages the potential of IPR (Andersen & Konzelmann, 2008). Such activities ensure that actors do not develop their parts of the system-level solution in silos, and perhaps more broadly, they allow for the formation of a holistic vision of how the parts of a complex, systemic solution fit together in increasing the sustainability impact of the output. This is the first point in need of change in the IPR system.

Second, and as a direct consequence of the first problem, the current IPR tools (that is, the structures related to granting of rights, scope of protection, enforcement, as well as the licensing models used) are not generally supportive of the shared alignment structures central to the systemic collaboration model, but rather regulate the activities of the actors in an individualistic way. Consequently, when a certain innovation ecosystem is driven by principles broader than economic sustainability (such as environmental, social or cultural sustainability), the current IPR system might fail to support it, because it advocates principles for collaboration that are not in line with those of the ecosystem itself. In other words, even in an innovation ecosystem driven by environmental sustainability objectives, IPR might continue to regulate individual streams of innovation based on economic sustainability and profit maximisation. For example, if the purpose of an innovation ecosystem is to promote sustainable innovation in a certain technological area (e.g., sustainable transport and electric cars), then if this same goal is not also the driving goal of the IPR system that governs and regulates the activities of the organisations operating and innovating in such an ecosystem, it is difficult to ultimately reach the objective of increased system-level sustainability. Thus, for IPR to support systemic collaboration for sustainable innovation, there is the need to align both its principles (theories) and structures (tools) with the requirements for governing systemic collaborations for sustainable innovation.

That said, we are not arguing that the different dimensions of sustainability - particularly, economic, on the one hand, and environmental, social and cultural, on the other - are inherently incompatible and cannot all be embedded in the IPR system. Nor are we saying that the environmental, social and cultural dimensions of sustainability are totally foreign to the current IPR system. Rather, the point is that the current theories used to justify our IPR system tend to prioritise economic sustainability, thus making it difficult to balance the different dimensions of sustainability in the context of systemic collaboration. Indeed, it could be argued that the above-presented concerns are the main reasons why most of the IPR solutions put forward in relation to firm-centric and user- and community-centric OI models have failed to varying degrees in promoting multi-stakeholder collaboration for sustainable innovation.

For example, one such attempt has been the creation of so-called patent (or in general IPR) pools, or other joint licensing types of agreement, which fall under the category of firm-centric OI IPR arrangements. IPR pools are agreements between two or more parties to cross-license parts of their current or future IPR portfolios related to certain technologies to one another or to third parties (WIPO, 2012). Typically, in these structures, licensing occurs via mutual coordination or via a third-party administrator. IPR pools were originally developed to tackle the problems that the increased number of patents (especially in certain industries, such as ICT) would cause in society, such as high transaction costs associated with the large number of multiple and at times overlapping IPR, or the use of patent thickets that slow down the development and commercialisation of innovations. Thus, IPR pools are especially appealing when dealing with complex and interoperable technologies, where multiple players can join in bringing their own complementary strengths – and hence show promise for supporting systemic collaboration for sustainable innovation as well.

It is worth mentioning that, although initially viewed with hostility by the regulator due to their potential clash with competition law, IPR pools are nowadays quite accepted by competition authorities. However, they remain problematic from the viewpoint of systemic collaboration for sustainable innovation for a number of reasons. First, alliances based on IPR pools still carry the risk of anticompetitive behaviour to the detriment of consumers and other stakeholders (Pourrahim, 2021). Second, and more importantly, IPR pools are driven by the very same goals the IPR system is built on - namely, profit maximisation - with other values like environmental, social, or cultural sustainability being considered only as far as they do not clash with the primary goal of economic sustainability. Moreover, IPR pools rely on a strong private ownership approach, in which a network of exclusive rights is set up to prevent competing uses. As a result, while IPR pools can partially support the co-specialisation of a selected group of actors around a system-level solution (e.g., a common technology), they do so in a limited manner by only enabling existing alliance partners to share or provide access to certain selected IPR protected technologies. As an example, IPR pools do not necessarily allow actors to share the required know-how or training capacities needed to reproduce or even understand how the inventions in patents that are shared are made. This effectively inhibits actors from contributing to the development of system-level solutions based on the cumulative development of complementary technologies.

Another IPR tool for promoting OI and multi-stakeholder collaboration has been the so-called IPR pledge. This instrument is primarily used in the context of the firm-centric OI model, although at times also used with user- and community centric models (e.g., in copy-left types of licences). For instance, IPR pledges have thus far been used on various occasions in the software context, but also by car and consumer electronics manufacturers, and recently also in the context of Covid-19 needed medical equipment and vaccines. IPR pledges are publicly announced interventions by IPR owners 'to out-license active patents (or in general IPR), to the restricted or unrestricted public, free from or bound to certain conditions for a reasonable or no monetary compensation' (Ehrnsperger & Tietze, 2019). As such, IPR pledges are different from IPR pools in the sense that - depending on the conditions - pledges might not necessarily benefit certain defined groups of actors that have made formal agreements amongst each other (i.e., they are not purely firm-centric types of models). Instead, IPR pledges sometimes include types of IPR licensing typical of the user- and community-centric models and they can apply to the larger public. As such, they hold more potential for systemic collaborations for sustainability (Ballardini et al., 2022).

An example of an IPR pledge relevant to our discussion is the patent pledge announced by Tesla in 2014 in sustainable transport. According to this initiative Tesla 'will not initiate a lawsuit against any party for infringing a Tesla patent through activity relating to electric vehicles or related equipment for so long as such party is acting in good faith' (Tesla patent pledge, 2014). The primary aim is to foster developments in the sustainable transport sector and 'encourage the advancement of a common, rapidly-evolving platform for electric vehicles, thereby benefiting Tesla, other companies making electric vehicles, and the world' (Tesla patent pledge, 2014). One of the main reasons for Tesla's decision relates to the fact that there are major patent thickets surrounding electric cars and green transportation which impede further developments in this area, illustrated, for example, by the dispute between Paice LLC and Toyota Motors over patents for hybrid cars (Rimmer, 2018). Similar patent pledges are also in use in other areas of green

technologies (Awad, 2017). Examples include the Eco-Patent Commons founded by IBM, Nokia, Sony and Pitney Bowes, the GreenXchange launched in 2010 by inter alia Nike, Best Buy, Yahoo, and Creative Commons, and Canada's Oil Sands Alliance – COSIA - between twelve leading oil sands producers. Lately, in relation to the COVID19 crisis larger initiatives like the Open COVID Pledge have also been launched (Open COVID Pledge).

Indeed, voluntary pledges to make IPR broadly available can overcome the administrative and legal hurdles faced by more elaborate legal arrangements such as patent or IPR pools (Thambisetty et al., 2021; Contreras et al., 2020). Notwithstanding the possible advantages, however, IPR pledges also suffer from limitations vis-à-vis systemic collaboration for sustainable innovations. One main concern relates to the fact that IPR pledges remain dependent on the IPR owner (who pledges), again maintaining the central feature of the IPR system focused on private ownership and individualism. In addition, IPR pledges carry some of the same problems as IPR pools in terms of enabling actor co-specialisation, because what is licensed out with IPR pledges is also only the IPR. This normally leaves both know-how and training capacities outside this arrangement. Moreover, the conditions of pledging are very different from one pledge to another, creating fragmentation and uncertainty while having to navigate amongst many different conditions. In addition, IPR pledges are normally temporary in duration and narrow in scope (e.g., only applicable to specific technologies). The temporary element might become particularly problematic in cases where new innovations are developed based on the protected technologies that are pledged. After the pledge expires, parties who have invested resources in the development of complementary assets might end up in difficult licensing negotiations with the IPR owners who originally pledged. Therefore, even if IPR pledges are fast and not heavily administrative tools, allowing different actors to develop solutions around some common technological core, they might be too limited when we look at the larger multi-technology innovation ecosystems in focus in the systemic collaboration for sustainable innovation model.

4.2. Reframing IPR to support systemic collaboration for sustainable innovation

How then can IPR become a system that supports systemic collaboration for sustainable innovation? In other words, how can IPR support the co-specialization of heterogeneous actors, drawing on shared alignment structures, to favour cooperative choices at all levels of decision-making, as well as resilience and collectivism in the development and scale-up of system-level solutions? In one vision, the futurist Rifkin suggested that monopoly capitalism will be displaced by a collaborative commons in which 'prosumers are plugging into the fledgling Internet of Things (IoT) and making and sharing their own information, entertainment, green energy, and 3D-printed products at near zero marginal cost' (Rifkin, 2014). While a somewhat utopian vision, it invokes a broader discussion of the constraints of the present IPR system and avenues forward with collaborative frameworks for sustainability-oriented innovation.

As a step in this direction, a vocal scholarship stream has arisen in recent times, which critically looks at the needs that sustainability introduces to re-shaping the fundamental constructions of private law (where IP law belongs to) in general, that is, the person, property, contract, tort liability, and remedies (Micklitz, 2015). Particularly in relation to the constructions of property (the tangible or intangible items or attributes that can be owned by a person or entity) and contract (an agreement between parties, creating mutual obligations that are enforceable by law) – which are the most central constructions of private law in the context of IPR – recent research calls for a rethinking of the mainstream economic and incentive-based approach in private property rights deriving from utilitarianism. For example, Ballardini : 4) et al. (2021) argue that "this system promotes individual autonomy by decreasing information and transaction costs, as well as collective action problems" (see also Doremus, 2011). However, one of the key characteristics of this type of owner-centric approach is that each owner is viewed as a 'gatekeeper' holding rights that, when exercised, bind all others (including third parties) to the owner's decisions (Butler, 2017). This is very problematic in the context of sustainability, in which other values like efficient use of resources should be prioritized over the economic expectations and interests of individual owners.

Notwithstanding the increased awareness on these matter in academic discussions, however, there is still a long way to go to reach these targets within the IPR system. To this end, we argue that for IPR to become a facilitator of systemic collaboration for sustainable innovation, changes are needed in both pillars of OI, namely the public ordering tool pertaining to the IPR forms of protection and enforcement and the private ordering tool pertaining to licensing schemes which also condition the governance model at stake.

Changes in the pillars of OI are to derive from changes in the theoretical frameworks that justify the whole IPR system. As previously mentioned, the current IPR system strongly relies on and largely takes for granted the utilitarian arguments that advocate profit maximisation and private ownership. This leads to several challenges in the context of systemic collaboration for sustainability as presented in Section 4.1. Thus, it is important to expand the philosophical grounding of the IPR system with broader moral and ethical considerations. For instance, Ballardini et al. (2021) and Hossain and Ballardini (2021) have argued that to trigger a change towards more sustainable innovations, other theories besides utilitarianism could be used as a basis for IPR policy-making. One such theory is the social planning theory (Wilkof, 2014). This is rooted in ideas that IPR should be shaped to help foster achievement of a just and attractive culture, and to enable a flourishing civil society (Fisher, 2001). Similarly, other theories such as distributive justice theory could also be relevant (Rawls, 1971). This approach holds that the legal arrangements themselves, as well as the associated institutions and procedures, can affect basic individual preferences in a way that will make them more acknowledging of others and more willing to cooperate, allowing the extension of collective utility frontiers (Fisher, 2001). While ambiguous in terms of the needs and goals these theories seek to promote (Wilkof, 2014), such theories could direct the development of IPR, as the public ordering tool of OI, to support new practices that allow more cooperation, resilience, and welfare maximisation, for example by enabling the legislator and judges to develop more concrete rules and practices in IPR that promote cross-industrial collaboration geared towards environmental sustainability.

Changes in the first pillar of OI, in turn, can trigger improvements in the second pillar –licensing – as well, which, consequently, would also drive changes in the governance framework at stake. In this regard, an interesting way forward could be as simple as further developing some of the existing frameworks used by the user- and community-centred model, such as the open source licensing model. As we have seen, the user- and community-centred OI models rely on the copyleft licence idea, in which copyright owners (e.g., of the code or other work) open up their IPR via open source licences that grant a royalty-free right to 'run, modify, distribute, and redistribute' modified versions of their work (Välimäki, 2005). This is a way of licensing IPR that enables collaboration among multiple users in a relatively simple manner (Välimäki, 2005). With open source software and hardware licensing, the conditions of the licences not only regulate the activities of the developer, but they also shape the way further developments occur. In the case of software, for example, free and open source licences (FLOSS) are guided by an ecosystem principle that primarily relates to "keeping the code open". To reach this goal, the regulatory structure of the FLOSS licence dictates certain conditions that allow software to be freely copied, modified, and distributed. In this way, the IPR licensing is not only in line with the ecosystem's principle, but it also triggers a governance structure in which that principle is passed on to follow-up innovations as well. Indeed, this model can encourage heterogeneous actors to get

involved in the innovation process, as well as promote deeper levels of collaboration and knowledge sharing (beyond mere sharing of the IPR) that can foster actor co-specialization within the ecosystem. But how can we use the tools of copyleft licensing, which are already in use in OI, to trigger a change towards environmentally sustainable innovations as well?

A new licence, which we tentatively call an "environmentally sustainable open source" (ESOS) licence, could be developed in this context. The driving principle of innovation based on an ESOS licence should be "environmental sustainability". In practice, this could mean that the inventors of "environmentally sustainable innovations" could license out their innovations under an ESOS licence, allowing third parties to freely copy, use, make, modify and distribute innovations, as long as these innovations are also used for researching or developing "environmentally sustainable innovations". This could provide the legal basis for systemic collaboration for sustainable innovation by supporting the formation of collaborative arrangements based on non-hierarchical alignment structures for sustainability-oriented innovation activities. This, in turn, would mean that not only the IPR are licensed out, but also cooperation would be triggered via enabling the sharing of knowhow and training capabilities, thus promoting co-specialisation among heterogeneous actors. Clearly, the model would be 'free as in free speech, not as in free beer', as with FLOSS (Stallman, 2002), to ensure that the costs of R&D are covered and expected profits fairly distributed – although profit maximisation would not be the driving principle of this ecosystem.

"Environmentally sustainable innovations" is certainly a concept that would need to be further developed for this proposition to work. It is not our intention here to go into the details of how such innovations should be characterised, but it is worth pointing out that initiatives towards this direction are already under way. For example, at ISO level a 'circularity standard' (ISO/WD 59020) is currently being developed. Moreover, in various patent systems the definition of "green technologies" is on the rise, for example in relation to the fast track of green patents (WIPO, 2013). Once in place, initiatives of this kind could very well form the criteria that could be used in the context of ESOS licences as well.

It is also important to note that in the sustainability innovation context, the IPR to be licensed out might not only be copyright (which represents the foundation for copyleft licensing) but also registered forms of IPR, such as patents. Certain types of copyleft licences (most notably the Apache 2.0 licence and others used in the open hardware context, like CERN licenses) already include express patent licence grants, even though the scope and key variable (i.e., who is granting a patent licence and what patents/activities are included) of such express patent licence grants varies among different licences (Haapanen, 2017). Moreover, arguably at least, some copyleft licences may provide an implied patent licence (Haapanen, 2017). In developing these new ESOS licences, it would be important that the terms of the licence are not only limited to copyright, but also include other IPR, such as patents. For example, this could be achieved by including in the conditions of ESOS licences not only the grant of the right to "copy" (that is, an exclusive right that falls under the copyright domain), but also the right to "use" or "make" (which are, rather, exclusive rights associated with patents).

5. Synthesis

Synthesizing the discussion above, our analysis draws attention to three specific ways in which changes in the IPR system and IPR tools can support systemic collaboration for sustainable innovation (see Fig. 1).

First, the theories that justify the IPR system (Fig. 1, A), as well as the structures of the licensing models used (Fig. 1, B), have traditionally prioritized individual ownership and the maximization of economic profits. This contradicts the objectives of systemic sustainable innovation that place emphasis on social, environmental and / or cultural values alongside economic objectives, as well as the sharing and diversification of knowledge among actors to accomplish system-level change. Thus, changes in the fundamental justification of the IPR system, for example toward theories of social planning and distributive justice, are needed to align the principles of IPR protection with the objectives of systemic sustainable innovation (Fig. 1., I). This alignment creates grounds for the productive use of IPR in systemic collaboration for sustainable innovation as it raises the priority of environmental, social and/or cultural objectives alongside economic objectives, and thus allows these objectives to be more easily embedded in the alignment structures (such as system-specific roles, participant responsibilities) that govern systemic collaborations.

Second, the ways in which IPR tools regulate innovation activities have a significant impact on the conditions under which systemic collaborations for sustainable innovation can emerge and gain momentum. As discussed above, the existing IPR system and IPR tools regulate innovation activities in an individualistic manner and steer the governance of individual streams of innovation toward closed arrangements dominated by the IPR holders. Thus, changes in both the IPR system and IPR tools are needed to remove obstacles from IPR sharing (Fig. 1, II). For instance, new IPR tools such as the ESOS license can enable actor co-specialization by incentivising actors to contribute their resources to the development of system-specific solutions (e.g., by reducing the risk of the IPR holder to appropriate financial benefits from collaborative innovations). Furthermore, such new IPR tools can direct the formation of mutual alignment structures to support openness and involvement of new actors in contributing to the cumulative evolution of the system-level solution by ensuring that the principle of systemic collaborations is passed on to follow-up innovations (i.e., using the innovations of others in the creation of sustainable innovations).

Third, available IPR tools influence systemic collaboration for

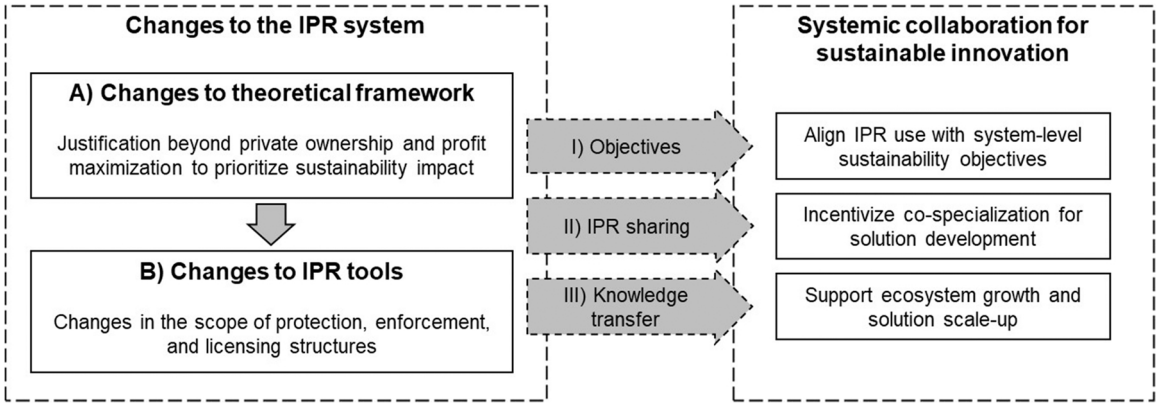

Fig. 1. Enabling systemic collaboration for sustainable innovation through changes in IPR.

sustainable innovation not only by enabling or limiting the sharing of IPR among collaborating actors, but also by regulating the conditions for sharing relevant knowledge and mutual learning around IPR protected innovations. For instance, open licence structures such as the ESOS can trigger alignment structures for systemic collaborations in which the open sharing of knowledge among actors boosts co-specialization in the development of the system-level solution (Fig. 1, III). Furthermore, the open sharing of knowledge, along with the feature of open license structures which passes the principle of sustainable innovation to follow-up innovations, enables new actors to engage with and contribute to (initially local) systemic collaborations, which speeds up the cumulative development and scale-up of the system-level solution.

6. Concluding remarks and avenues for future research

With growing impetus for finding system-level solutions to sustainability challenges, new forms of collaboration are becoming increasingly central to accomplishing system-level changes in the spirit of strong sustainability, forms that extend beyond current OI models. In this paper, we present a model of systemic collaboration for sustainable innovation, characterized by the co-specialization of heterogeneous actors in the creation of a system-level, sustainability-improving output governed through shared alignment structures. While previous literature has expanded our understanding of different kinds of ecosystems for supporting innovation and economic activities more broadly (e.g., Adner, 2017; Jacobides et al., 2018; Thomas & Autio, 2020), assessment of their potential for supporting systemic innovations for sustainability has been limited. Our argument is that systemic collaboration can provide avenues for the development and scale-up of system-level, sustainability-improving solutions that comprise several interconnected technologies and rely on the contributions of actors with complementary assets and know-how.

Moreover, we argue that while the existing IPR frameworks can, at least partially, support systemic collaboration for sustainable innovation, they also involve specific limitations that can impair the development and scale-up of system-level, sustainability-improving solutions. Specifically, changes in both the IPR justification principles in general, and IPR structures and tools (incl. governance) in particular, can offer steps forward towards supporting systemic collaboration for sustainable innovation: First, by increasing the salience of environmental objectives as the basis of IPR in general; second, by supporting the productive sharing of IPR for actor co-specialization, and; third, by shifting the focus of IPR structures and tools from limiting access and use to supporting knowledge sharing that enables actors to build on sustainable innovations in a cumulative, system-changing manner.

This analysis raises several interesting questions for future research. First, more detailed analysis is needed to explore how potential changes to the IPR system, or the use of particular IPR frameworks such as the proposed ESOS license, translate into productive systemic collaboration. As pointed out above, systemic collaboration for sustainable innovation places a high premium on knowledge sharing, which enables actors to develop complementary assets and competences for the development and delivery of system-level solutions. In this sense, new IPR tools are important for creating legal frameworks that support knowledge sharing and actor co-specialisation. However, to leverage the productive potential of novel IPR frameworks, systemic collaboration for sustainable innovation must also draw on appropriate social structures and practices that enable actors to efficiently coordinate interactions, share knowledge, resolve conflicts, and distribute benefits in alignment with the affordances of the new IPR tools (Andersen & Konzelmann, 2008). Hence, future research is needed to explore in more detail how system-specific alignment structures, such as modular ecosystem roles and business models for value capture and sharing, can tap the productive potential of current and new IPR frameworks for systemic collaborations for sustainable innovation, as well as how the ways of using IPR and governing collaborative innovation activities differ between different types of ecosystems (e.g., Masucci et al., 2020).

Second, a central issue in the application of current and novel IPR tools for systemic collaboration for sustainable innovation pertains to balancing the collective objectives of systemic sustainable innovation with the appropriation of economic value from collaborative innovation and the distribution of benefits between collaborating actors. This creates a dilemma for the design and use of new IPR tools in systemic collaborations. On the one hand, investments in system-specific resources are necessary for the success of a system-level solution but entail additional costs for the organisations involved (Jacobides et al., 2018). Thus, IPR tools need to provide adequate control over IPR for the inventors to enable value appropriation and motivate collaborative innovation efforts in the short run. On the other hand, it is equally clear that IPR tools based on private ownership and profit maximization inhibit systemic collaboration for sustainable innovation in several ways, as discussed both above and in previous literature (e.g., Alexy et al., 2009; Andersen & Konzelmann, 2008; Monteiro et al., 2016), creating a need for changes in the current IPR system as well as the available IPR tools. However, this raises the question how the new IPR tools, and the ways in which they are utilized in systemic collaborations for sustainable innovation, ensure the short-term incentives for contributors while directing joint innovation efforts toward system-level sustainability objectives.

For example, if the use of ESOS-type licences limits the incentives of companies to invest in new technological infrastructures that constitute the backbone of sustainable solutions at the systemic level, systemic collaboration for sustainable innovation may rely extensively on the involvement of the public sector in ensuring that “the code”, i.e., the system’s core technology, remains open for actors to use for sustainability-oriented, systemic innovations. Thus, future research is needed to explore in more detail how new IPR frameworks, particularly those geared toward sustainable innovation, and the alignment structures within which they are put into use, influence the formation and evolution of systemic collaboration for sustainable innovation in the context of different technological fields.

Finally, we have made a case in this paper for the need for new theoretical grounds for the IPR system to enable systemic collaboration for sustainable innovation. At the same time, research on sustainability transitions reminds us about the complex technological, economic, social, and political processes that shape broader, system-level transitions (e.g., Geels, 2004; Markard et al., 2012; Smith et al., 2010). While our emphasis with systemic collaboration has been on the ability of such collaboration to produce new “prototypical” system architectures that enable more sustainable modes of production and consumption, based on novel IPR justifications, structures and tools, the question remains as to how these initially local solutions penetrate the regime (i.e., industry or national) level. For example, national innovation, economic, energy, and other policies both create conditions for local systemic collaboration and shape the pathways through which they contribute to systemic transitions (e.g., Fagerberg, 2018; McMeekin et al., 2019).

In this broader perspective, an interesting question for future research is the role that the IPR system and available IPR frameworks play in broader sustainability transitions (e.g., Tietze et al., 2017). For example, it could be argued that collaboration based on the here-proposed broader justifications of the IPR system, as well as on the developed idea of the ESOS licence, could speed up systemic transitions around novel technologies by enabling the application and modification of core technologies cumulatively by an expanding group of actors. However, as the use of IPR is intricately interwoven with system-specific alignment structures and business models of solution-specific ecosystems (e.g., Bolton & Hannon, 2016), institutionalized in the context of different industries, and interacts with national and international regulation and innovation policy, more research is needed to explore the implications of current and novel IPR for sustainable innovation at a systemic or societal level alongside other policy and regulatory interventions.

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CRediT authorship contribution statement

Jaakko Siltaloppi: Conceptualization, investigation, writing - original draft, writing - review & editing. **Rosa Maria Ballardini:** Conceptualization, investigation, writing - original draft, writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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