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ESSAY

Examining Open Innovation in Science (OIS): what Open Innovation can and cannot offer the science of science

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ABSTRACT

Scholars across disciplines increasingly hear calls for more open and collaborative approaches to scientific research. The concept of Open Innovation in Science (OIS) provides a framework that integrates dispersed research efforts aiming to understand the antecedents, contingencies, and consequences of applying open and collaborative research practices. While the OIS framework has already been taken up by science of science scholars, its conceptual underpinnings require further specification. In this essay, we

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critically examine the OIS concept and bring to light two key aspects: 1) how OIS builds upon Open Innovation (OI) research by adopting its attention to boundary-crossing knowledge flows and by adapting other concepts developed and researched in OI to the science context, as exemplified by two OIS cases in the area of research funding; 2) how OIS conceptualises knowledge flows across boundaries. While OI typically focuses on well-defined organisational boundaries, we argue that blurry and even invisible boundaries between communities of practice may more strongly constrain flows of knowledge related to openness and collaboration in science. Given the uptake of this concept, this essay brings needed clarity to the meaning of OIS, which has no particular normative orientation towards a close coupling between science and industry. We end by outlining the essay's contributions to OI and the science of science, as well as to science practitioners.

Contextualising Open Innovation in Science: recent debates and further refinements

Researchers and their institutions are increasingly advocating, fostering, and experimenting with more open and collaborative approaches to scientific research. Such efforts often target particular research outputs (e.g., scientific papers, data, code) or propose to bring researchers together with particular stakeholders (e.g., practitioners, citizens, researchers from other disciplines) in order to boost scientific productivity or democratise the research process (Sauermann et al., 2020). Recently, the Open Innovation in Science (OIS) Research Framework brought together dispersed knowledge about the role and value of applying open and collaborative scientific practices in a programmatic way (Beck et al., 2020).

Opening up the process of scientific knowledge production and dissemination has been the focus of other programmes of inquiry from Citizen Science to Responsible Research and Innovation. But OIS takes an approach that is both 1) integrative, drawing together heterogeneous practices rather than considering them in isolation, and 2) contingent, holding that openness and collaboration in science can advance particular outcomes like novelty, efficiency, and impact but are neither suitable under all conditions nor ends in themselves (Beck et al., 2020). Notably, OIS conceptualises openness and collaboration in terms of boundary-crossing knowledge flows, an approach inspired by management research on Open Innovation (OI; Bogers et al., 2017; Chesbrough, 2019).

The OIS approach has already been taken up by science and innovation scholars, who have sought to apply it to novel empirical contexts and to critically examine its underlying assumptions (e.g., Dahlander et al., 2021; Gkeredakis et al., 2021; Gold, 2021). This, in turn, has highlighted the need for clarification and further refinement. In this essay, we delineate what the concept of OIS does and does not borrow from OI, and we offer a more precise account of the boundaries whose crossing comprises the central concern of OIS. By doing so, we acknowledge the need to adapt concepts initially developed in the context of research on private-sector firms for use in the science context, even as we underscore that science contexts are themselves plural. As such, we depart from orthodox accounts of organisational boundaries in OI research and take a community-of-practice

approach to consider epistemic, professional, and cultural boundaries at multiple scales, a move that both responds to the specificities of the science context and contributes to debates within mainstream OI research.

One potential concern with respect to the OIS approach is the undermining of 'pure' basic research, which is sometimes viewed as the essence of academic science. Yet even in the absence of exogenous pressures, the nature of the scientific problem to be solved has long defined the form of knowledge production that scientists employ (Haeussler & Assmus, 2021). Research and researchers can move over time between the polarities of basic and applied science, even as concepts like use-inspired basic research (Stokes, 2011) and engaged scholarship (Van de Ven, 2007) challenge any notion of a linear continuum along which projects can be placed. As historians of science have argued, the effort to establish and shore up such binary distinctions can best be seen as a practice intended to 'bridge the gap between the promise of utility and the uncertainty of scientific endeavor' (Schauz, 2014, p. 277).

Another potential concern is the diluting of a maximalist vision of Open Science, as originally defined by a core group of scientific activists. But today, both practitioners and analysts of Open Science are exploring alternative genealogies of the movement and seeking to assess 'for whom science is being opened, by whom, [and] who stands to benefit' (Chan et al., 2019, p. 18). Through a wide-ranging consultation process leading to the formulation of a UNESCO (2021) recommendation to member states, principled limitations on openness have been recognised on the basis of national security, confidentiality, privacy, and respect for subjects of study. So, while the contributions of early advocates were pioneering and essential, today's more diverse and critical Open Science movement is challenging the very idea of focal members who are authorised to speak definitively on its behalf and who must not be alienated at any cost (Bahlai et al., 2019).

In the remainder of this essay, we proceed by clarifying the relationship between the OIS Research Framework and OI more broadly, with particular attention to defining the boundaries that we understand knowledge flows to cross in the context of openness and collaboration in science (section 2). Then, we present an example of how one concept employed in the OI literature can offer fresh analytical traction on developments in the organisation of research funding that entail applying OIS approaches (section 3). A discussion of the implications and limitations of our approach, including its contributions to OI and the science of science, concludes the essay.

Conceptual underpinnings of OIS: building on OI principles while addressing the specificities of the science system

What OIS can learn from OI

Let us be clear: by putting forward the concept of Open Innovation in Science, we are neither calling for more scientific participation in industry-driven OI nor do we see OIS, in the first instance, as an effort to achieve a 'closer coupling' (Heimstädt & Friesike, 2020, p. 1) of industry and science. Rather, we argue that the ideas about new ways of producing knowledge and creating value developed and tested in OI research may help us to understand contemporary developments in science. As diverse as the science system

is, we suggest that widespread trends towards greater openness and collaboration have consequences across contexts and levels of analysis that OI scholarship can potentially illuminate.

For example, at the individual level, research shows that scientists are increasingly seeking to engage other stakeholders who are not scientific professionals (e.g., members of the general public or specific interest groups such as patients, policymakers, and industry partners) at one or more stages of the research process (Nature editorial, 2021). However, to successfully collaborate with actors across various kinds of epistemic, professional, and cultural distance may require a different set of skills and capabilities than scientists typically obtain through their academic training. OI research can point us towards one such characteristic: absorptive capacity, i.e., the capability to successfully recognise, assimilate, and exploit external knowledge (Cohen & Levinthal, 1990) so as to engage in OI practices (e.g., Lowik et al., 2017). Grounded in the logics of OIS, we suggest that scientists who are given opportunities to increase their absorptive capacity may also be better equipped to apply open and collaborative approaches to science, such as partnership-based research (Nyström et al., 2018). Such projects often demand the ability to identify, assimilate, and apply knowledge that is shared in unfamiliar ways. Thus, by applying a concept deployed in OI research in the context of science, both researchers and practitioners can draw on operationalisations of absorptive capacity and explore their suitability for the science context.

Similarly, at an organisational level, universities and other research-performing organisations are engaging in a range of strategies to foster knowledge exchange with external stakeholders. Indeed, some have begun to call for remaking universities in the image of 'open knowledge institutions' (Montgomery et al., 2021). Research has shown that firms applying OI principles are more likely to source external knowledge than to transfer internal innovation outside of organisational boundaries (Chesbrough & Bogers, 2014). In contrast, scientific research organisations have well-developed structures to help scientists share final research outputs with other actors (e.g., via publications, technology transfer offices, or science communication offices), but comparatively less-developed structures for sourcing external knowledge (e.g., citizen science offices, research collaboration training). To understand this difference, OI research points us towards the need to consider value creation and value capture (Chesbrough et al., 2018). Yet the economics of science are different from free-market economics, as knowledge resources are often not rivalrous in use; OIS may, for instance, involve what have been termed 'inverse commons' (Raymond, 2001), where use by others can increase the value of the shared resource. By engaging with 'users' of scientific research (e.g., patients, community members), inbound knowledge flows can create generative appropriability and thus, increase the value captured for the user, the scientist, and the research organisation (Ahuja et al., 2013). But, considering the lack of existing incentives for research-performing organisations to pursue such engagement, it becomes clear that new or strengthened mechanisms for capturing value from these inputs (e.g., as reputation or access to funding) may be needed, so that research organisations are more likely to make the investments needed to foster the relevant open and collaborative practices.

Openness across the research process has, at times, been viewed almost as an end in itself instead of a means to improve outcomes. In contrast, OI has taken a contingent view on openness as a means, under certain conditions, to achieve greater business

productivity. Our formulation of OIS suggests that such a contingent view may be beneficial for science as well, such that openness is seen as a means to other ends that need to be situationally defined. In our previous work, we pointed to greater novelty, efficiency, and impact as ends that are specific to science contexts (Beck et al., 2020), although we do not regard this list as definitive. Rather, we credit OI as a source of inspiration for complementing a strongly ideological view of openness in science with a more pragmatic perspective that asks when, how, and under which conditions science needs to be open and collaborative – recognising that there may continue to be situations where restricting (or at least delaying) knowledge flows or scoping a project in narrowly disciplinary terms may be the optimal approach (Thursby et al., 2018).

Defining boundaries in the context of OIS, or, what OIS cannot learn from OI

The divergent social organisation of industry and science underpins a major difference between OI and OIS: the nature of the boundaries that knowledge flows are understood to cross in the definition of each concept. While OI research looks beyond the firm to understand the motivations of lead users (Jeppesen & Frederiksen, 2006) or the dynamics of open-source communities (Von Krogh et al., 2003), it typically considers the well-defined edges of the firm as a legal entity and formal organisation as the main boundary to be crossed. OIS, in contrast, concerns itself with more informally organised scientific communities that have historically cut across the formal organisations where scientific researchers were employed and certified the knowledge that researchers produce (Clark, 1987). Thus, members of multiple scientific communities can coexist within the same research organisation (e.g., labs or departments within a university), often working with a high degree of autonomy (Teece, 2018), which entails approaching boundaries and their crossing in a more plural and dynamic way.

We understand boundaries as the focal point of relational processes that unfold across a wide range of social phenomena, institutions, and locations (Lamont & Molnár, 2002, p. 168). This understanding is especially relevant to OIS because the diverse practices that we have designated OIS collectively require the consideration of a variety of epistemic, professional, and cultural boundaries and their interactions at multiple scales (Beck et al., 2020). Emphasising the multiplicity of these boundaries allows OIS research not only to identify the challenges and opportunities that may ensue from a lack of proximity between individuals, groups, organisations, fields, and societies (Boschma, 2005), but also to enable communication and knowledge exchange through the performance of boundary work (Langley et al., 2019).

Given the complex structure of the science system sketched above, we propose to take an approach inspired by the literature on communities of practice to defining boundaries, proceeding from the assumption that knowledge flows easily where practices are shared and 'sticks' where they are not (Brown & Duguid, 2001). The purposive management of knowledge flows as conceptualised by OIS thus entails contending with two types of challenges: a) situations where openness is *desired but difficult*: even if partners agree to share or collaborate, a lack of common practices may inhibit the flow of knowledge between them (e.g., different incentive regimes, high coordination costs); and, b) situations where openness is perceived as *possible but risky or threatening*: researchers may worry that knowledge 'leaks' will dilute their ability to capture value from their research

(Beck et al., 2019), while individuals, organisations, and communities may have normative preferences about who or what constitutes an acceptable knowledge partner (Pellé, 2016).

Boundaries, as defined by a community-of-practice approach, are arguably less visible and blurrier than those defined by formal organisational structures, perhaps more akin to the concept of the ecotone as a zone where habitats overlap (Gershon, 2019). The OIS approach does not discount the importance of formal organisational boundaries, given divergence in local expectations and pressures on research-performing organisations to distinguish themselves in an arena of global competition (Deem et al., 2008). Yet, we argue that clear and visible boundaries between organisations and their subunits may constitute less of an obstacle to openness and collaboration in science contexts, while blurry or even invisible boundaries between communities of practice may constrain the flow of knowledge (e.g., Liberati et al., 2016). For researchers and practitioners alike, invisible boundaries pose challenges because they may be more easily overlooked. Then again, given their lack of material grounding, invisible boundaries may also be more easily rendered porous, if not dissolved altogether.

Adapting ambidexterity to better understand developments in science

To further illustrate how concepts that have proven useful in OI can also shed light on developments in science, we draw in this section on the concept of ambidexterity, i.e., 'the ability to simultaneously pursue both incremental and discontinuous innovation' (Tushman & O'Reilly III, 1996, p. 24). On this view, organisations under conditions of environmental change face the fundamental challenge of balancing two distinct strategic approaches: exploitation, understood in terms of creating and capturing value from existing assets and capabilities, and exploration, understood in terms of laying the groundwork for future value to be realised through processes of search, risk-taking, and experimentation (March, 1991; Nobakht et al., 2021). Efficiently managing this challenge has been characterised under certain conditions as a prerequisite for organisational survival and success (Raisch et al., 2009).

The production of scientific knowledge, we argue, faces a similar requirement. The increasing amount of scientific knowledge over the last centuries has resulted in the organisation of science into disciplines, following the need for specialisation (Jacobs, 2017). As a consequence, knowledge gets organised into increasingly narrow subfields and scientific careers are structured around particular requirements within them, resulting in epistemic and social boundaries that are increasingly difficult to overcome. Yet, knowledge production is now hitting up against the limits of this strategy, as observable in incremental research advances, declining productivity, and higher resource requirements to reach the knowledge frontier (Bloom et al., 2020; Chu and Evans, 2021 Encouraged by the structures of the science system itself, scientists across all disciplines are prone to exploit existing resources (i.e., existing networks, proximate knowledge, established practices) while minimising their risk (e.g., grant and journal rejections, null results, delays, or other supposed failures) instead of searching for and experimenting with more exploration-oriented projects. But scientific breakthroughs require risky

research, i.e., novel recombinations of distant knowledge, often as assembled by inter- and transdisciplinary teams that can collaboratively tackle grand challenges from different perspectives (National Science Foundation, n.d.; Ulnicane, 2016).

Exploration strategies are less favoured by scientists in the early stages of their careers due to the high risk they incur (Franzoni & Rossi-Lamastra, 2017). Being trained and succeeding in a system that encourages (and sometimes may even require) an exploitation approach provides few incentives for changing that strategy. Organisation- and field-specific incentive structures such as tenure requirements and review processes that reward narrow specialisation further discourage the initiation of exploration-related projects. As such, the OIS Research Framework (Beck et al., 2020) recognises the multi-level factors that can undermine (or, alternatively, strengthen) the willingness and ability to pursue a strategy of exploration in scientific research endeavours.

Grounded in the logics of OIS, we surface the usefulness of applying the concept of ambidexterity to the science context. Here, the concept may be seen to refer to the ability to balance exploitation and exploration projects in science in order to efficiently manage today's knowledge demands while simultaneously laying the groundwork for (potential) future breakthroughs (cf. Benavides & Ynalvez, 2018). Ambidexterity can equally be applied at all levels of analysis in the science context: while individual scientists may develop such a capacity to balance tradeoffs between short- and long-term perspectives, organisations and scientific fields as a whole may balance their project portfolio towards having both incremental and radical research projects.

This line of reasoning illustrates how adopting a concept that became central in understanding the value of OI can benefit research on science. Employing the ambidexterity lens to analyse the problem of incrementalism allows us to take a fresh look at (changes in) the science system and to surface factors that prevent scientists from engaging in more exploration-oriented projects, so as to achieve a more optimal balance between exploration and exploitation. A sharper definition of the problem space helps us to identify, test, and evaluate strategies for addressing this imbalance.

In what follows, we present two real-world cases that illustrate how OIS approaches can tackle the disadvantages that exploration-oriented research faces in receiving external funding. Conventional funding schemes often fall short in distributing funding to projects characterised by higher levels of novelty, riskiness, and/or boundary crossing (Franzoni et al., 2021; Stephan et al., 2017). Even though OIS approaches are often analysed at the level of individual research projects and applied at one or more particular stages in the process of carrying them out (i.e., conceptualisation, exploration and/or testing, and documentation; Beck et al. (2020)), we focus here on the system level, regarding funding distribution as a particularly strong lever for changing the research landscape due to the scale and power of its effects (i.e., affecting the early stages of numerous research projects with a single programme). We argue that inflexible forms of governance (e.g., for intellectual property; see example 1) and existing biases in the funding process (e.g., novelty bias, expert bias; see example 2) can be analysed together with respect to the ways that they block scientists from initiating more exploration-oriented projects. In each of the cases, a set of actors experimented with approaches to improve the chances for exploration-oriented projects to receive funding and, thus, to rebalance the prioritisation of exploration- and exploitation-oriented research, thereby creating the conditions to further advance the knowledge frontier.

Table 1. Summary of commonalities and differences across the OIS cases.

	Case 1: Open Discovery Innovation Network (ODIN) in Denmark	Case 2: Crowdsourcing the Dutch National Research Agenda
Common features and objectives	- Resource allocation schemes applying novel open and collaborative approaches to increase funding chances for riskier, but potentially breakthrough research projects that might not otherwise get funded (i.e., exploration-oriented projects) - Balancing the project landscape by supporting the initiation of exploration-oriented projects to achieve scientific ambidexterity.	
Original purpose of the case	Facilitate the co-creation of open research involving academic scientists and pharmaceutical companies to accelerate the discovery of novel therapeutics and diagnostics.	Enhance impact, reach top positions in global scientific rankings, and increase legitimacy of scientific research by enabling society to influence the agenda and bring real-world problems to the table.
Scientific field	Health sciences	All fields
Stakeholders involved (within and beyond science)	(1) Industry (2) Academic scientists	(1) Members of the public (2) Other societal representatives (e.g., companies, NGOs, governmental organizations) (3) Academic scientists
OIS practices applied or fostered	(1) University-industry collaboration (2) Material and data sharing	(1) Crowdsourcing (2) Inter- & transdisciplinary collaboration
Challenges addressed to reduce the bias against funding exploration-oriented projects	For academic scientists: IP system in Denmark For industry: priority given to exploitation	Purely open calls for proposals tend to reproduce existing patterns of exploitation-oriented research activity.
What is the mechanism for supporting exploration-oriented projects to achieve scientific ambidexterity?	Application potential of scientific solutions can be enhanced in dialogue with industry partners.	Agendas are set by members of the general public, who bring in new perspectives about the relevance and priority of identified challenges.

Yet, the two cases also differ in several aspects, highlighting the relevance of OIS to diverse empirical contexts. They involve 1) different stakeholder groups, and entail the application of 2) different OIS practices, including both one- and two-way knowledge flows. They are being applied in 3) different scientific fields, and they target antecedents for increased exploration at 4) different levels of analysis. Table 1 summarises the similarities and differences of the OIS cases.

Case 1: private funding as catalyst for collaborative research (ODIN)

The Open Discovery Innovation Network (ODIN; https://projects.au.dk/odin) is a pre-competitive collaboration initiative, funded by the Novo Nordisk Foundation and based at Aarhus University in Denmark, which seeks to facilitate the co-creation of open research involving academic scientists and pharmaceutical companies (see Altshuler et al., 2010 for an overview of such initiatives). The goal of ODIN is to accelerate the discovery of novel therapeutics and diagnostics while laying the groundwork for future research collaborations beyond the funded project, which might themselves vary in their degree of openness and potential for revenue generation.

To facilitate these projects, ODIN has developed an ideation process leading up to the submission of formal funding applications. During this process, potential applicants from both academia and industry are required to share their project ideas with the ODIN community to source input and to enlist partners from the other sector in

authentic collaborations. This sharing takes place on a digital platform maintained by the ODIN secretariat, as well as through dedicated pitch sessions. From there, it falls to the participants to develop a common understanding of shared opportunities. In an initial application screening round, ODIN filters out project ideas that lack an orientation towards translational research, which are often evident in the nature of the applicant's engagement with the ideation process. ODIN strongly believes that there is a place for basic research, but with the funds that it has been entrusted the initiative wants to avoid funding projects that involve companies as token partners or mere recipients of results.

There are two barriers to exploration-oriented drug discovery research that the ODIN initiative seeks to resolve. First, the Danish IP system generally requires that academic researchers disclose discoveries to their university's technology transfer office, such that the university's intellectual property rights can be asserted, before discussing them with industry. Yet, researchers have observed that this requirement, when applied too stringently or at an inopportune point in the research process, could stand in the way of translation and delay the sharing of knowledge. By releasing scientists from the expectation of asserting IP rights for early-stage or precompetitive research, ODIN allows for the integration of industry insight into early stages of the research process. Yet, because the funding it awards is provided by a foundation and selection decisions are made by an independent steering group, ODIN also avoids undue influence of industry actors over academic research. Both internal R&D and contract research tend to be oriented towards near-term profits, a second barrier to exploration-oriented drug discovery research. But ODIN has found that companies participating in its co-creation process are willing to take greater risks with respect to the scientific focus of the projects, often also contributing in-kind funding and services or offering researchers the use of otherwise inaccessible materials. It remains to be seen whether these dynamics will persist as ODIN seeks to scale up and move towards a more sustainable business model. But for the time being, by overcoming organisation- and policy-level barriers to university-industry collaboration, ODIN is helping to achieve greater ambidexterity of the Danish research project landscape by supporting and funding exploration-oriented drug discovery.

Case 2: crowdsourcing the Dutch national research agenda

In 2014, the Dutch Ministry of Education, Culture and Science launched a new policy framework for developing a common national agenda for scientific research (see the chapters collected in De Graaf et al., 2017). In addition to enhancing the impact of research undertaken in the Netherlands, the agenda would aim to increase public legitimacy and support for research by enabling societal stakeholders to participate and bring research problems to the table. By targeting a portion of public research funding to identify research priorities, the agenda aimed to foster collaborations between universities, research institutes, and other partners from the private and public sectors.

Businesses, NGOs, and individual citizens were invited to submit 'researchable' questions through a pioneering public consultation process that yielded almost 12,000 questions. Then, with the help of software tools, five teams of researchers from across the disciplines reviewed, structured, and clustered the questions. Subsequently, a steering committee (including scientific and societal representatives) organised the clusters into 25 exemplary 'routes' that traced connections between multiple clusters. Researchers at a

Dutch research-performing organisation, with one or more collaboration partners from the public or private sectors, could then apply for funding related to one or more of these routes, which addressed broad societal challenges such as energy transition and inclusive development.

The head of the selection committee for the 2019 funding round described this comprehensive, bottom-up process as 'an experiment with a new democratic governance of scientific research' (Bijker, 2020). While public participation in scientific agenda setting has become increasingly common, the meaningful integration of this input and the explicit focus on multidisciplinary and multi-institutional consortia make the Dutch National Research Agenda an exemplary OIS case at the ecosystem level. By expanding on the one hand priority setting and on the other project team composition to a wider set of stakeholders, the initiative is helping to expand available funding pathways for novel research ideas that come from outside of established scientific agendas and paradigms. As such ideas often require exploration-oriented projects, the Agenda contributes to achieving greater scientific ambidexterity of the Dutch research landscape.

In summary, the OIS approach can offer a fresh perspective on problem spaces emerging in the contemporary science system, as seen in the example developed in this section of looking at the incrementalism of scientific projects through the lens of ambidexterity. The cases discussed above apply different OIS practices to confront this trend and, thereby, increase the likelihood for exploration-oriented projects to receive funding. These cases differ widely in terms of scientific fields, stakeholder groups involved, one- and two-way knowledge flows utilised, and types and levels of challenges encountered. But bringing them together through the concept of ambidexterity as applied in the context of science can point us towards novel insights synthesised from research in the concept's original domain of application. For instance, the literature on organisational learning in firms indicates that successful organisations identify linkages between exploration and exploitation strategies and adjust their relative emphasis in response to changing internal and external environments (e.g., Gupta et al., 2006). While in a firm context it is more common for exploitation to occur at the expense of exploration, the reverse may hold in the science context. Thus, while we might assume that it is uncommon or even impossible to have over-exploration in science, science of science scholars can put this notion to the test by looking for patterns of optimal settlement of the tradeoff between exploration and exploitation strategies.

Conclusion and contributions

In this essay, we took stock of the initial uptake of the Open Innovation in Science (OIS) concept and clarified its conceptual underpinnings. More specifically, we discussed how OIS builds on principles derived from Open Innovation (OI) research but goes beyond describing or advocating for science commercialisation. First, we posit that ideas developed and tested in OI research, including a contingent view on openness as a means rather than an end, may help us to better understand contemporary developments in science and to evaluate the role and value of openness and collaboration. Second, we push past the traditional focus on well-defined organisational boundaries in OI research. Instead, we centre the blurry or even invisible epistemic, professional, and cultural

boundaries that OIS practices entail crossing, an approach inspired by the literature on communities of practice that is better able to respond to the realities of the science context.

The two key points advanced in this essay make a number of contributions to research on the science of science (e.g., Dasgupta & David, 1994; Fortunato et al., 2018) as well as the Open Innovation field (e.g., Bogers et al., 2017; Chesbrough, 2019). By modelling open and collaborative scientific research in terms of knowledge flows crossing certain boundaries, we open the way for science of science scholars to draw on OI insights into how such knowledge flows can be purposively managed and optimised without sacrificing freedom of scientific inquiry. And, by defining boundaries situationally in terms of where knowledge 'sticks' or flows easily on the basis of shared practices, we advance an understanding that may encourage scholars from diverse research communities such as team science, the economics of science, or STS to collectively trace the construction and distribution of such boundaries and to experiment with tools that help to enable, initiate, and manage knowledge flows across them. By reshaping the field, an integrative research agenda can spark novel scientific breakthroughs. But OIS research can also contribute to the OI field. Following the OIS understanding of boundaries, we invite OI scholars to consider other-than-organisational boundaries in their conceptualisation of knowledge flows in an industry context. OI scholars may also stand to learn from the longstanding experience of scientific researchers and their organisations in creating and capturing value from outbound knowledge flows (e.g., disclosing and discussing preliminary findings), thus complementing the conventional focus of OI research and practice on inbound knowledge flows (West & Bogers, 2014). Here, engaging with other institutional logics on their own terms may allow OI scholars to bring novel insights to bear on the industry context that remains their primary point of reference.

Not only scholars but also science practitioners such as policymakers, funding agencies, and administrators of scientific organisations can benefit from the insights presented in this essay. First, calls to engage in open and collaborative research practices should emphasise the importance of purposively enabling, initiating, and managing knowledge flows. Hence, for instance, grant proposals should be evaluated not only based on their intention to involve citizens or other stakeholders, but also on fitness for purpose and (willingness to develop) capabilities and resources for anticipating and addressing obstacles to knowledge co-production. With such evaluation criteria in place, it may be possible to increase the proportion of successful open and collaborative research projects. Second, considering the integrative nature of the OIS concept, science practitioners (and the research that they seek to support) may benefit from moving away from calls for the application of particular OIS practices (e.g., citizen science, university-industry collaboration, data sharing) and towards expectations to effectively collaborate and share with different stakeholders – at different stages of the research process and to different degrees – as a new standard. This shift would entail a movement from the idea of 'openness and collaboration' as being considered as *ends* of a research project rather to being considered as *means* to ends such as overcoming incrementalism, as seen as in the two OIS cases. In sum, we hope that this essay will stimulate researchers from disciplines concerned with the science of science as well as science practitioners to engage in

discussions about new ways of organising scientific knowledge production and dissemination, with the aim of making science more novel, efficient, and impactful.

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