RESEARCH PAPER

As open as possible, but as closed as necessary: openness in innovation policy

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# ABSTRACT

Innovation research has grown steadily over the years, with different foci and methodological approaches. The abundance of literature on the topic makes clear that innovative processes are at the centre of many narratives, in academia, the public sector in general, and in industry. This contribution scopes the literature and traces some key considerations regarding a determining factor: openness. The paper explores the literature in order to narrow down the characteristics of so-called ‘open innovation’. An emphasis is placed on the main channels that determine collaboration practices, particularly between academia and the private sector, namely university-industry linkages. It focuses on open transfers of knowledge and open science research practices. The overarching discussion develops key questions underlining the relevance of open innovation for science, industry, and the consolidation of narratives promoting access and collaboration. The paper concludes by offering some insights into trends and challenges from a research perspective as well as from the view of innovation dynamics.

# Keywords: innovation, open innovation, openness, science policy, university-industry links, knowledge flows, intellectual property rights

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# Introduction

Open science represents a cornerstone, and one of the most dynamic and current characteristics of research and development (R&D) environments (Picarra, 2015; Bogers *et al.*, 2018; Aziz *et al.*, 2020; de Beer, 2020; Barrett *et al.*, 2021). However, open scientific practices carry inherent challenges and potential pitfalls, both as a research framework and as a policy objective. In research, openness entails paradigmatic shifts in scholarly praxes that, under disciplinary-specific conditions, may enable or hinder the broad spectrum of the open science repertoire. In policy, open science challenges prevailing intellectual rights protections as well as the institutional capacity to keep up with a dynamic sector. These two dimensions have repercussions for complex and uncertain production networks (Chesbrough, 2019; de Beer, 2020) which are driven by various types of linkage. Hence, the discussion seeks to outline the ways in which openness has become inscribed into national, regional and international policy: (a) as an instrument with which to stimulate collaboration within and between sectors (Azagra-Caro *et al.*, 2022) as well as (b) a theoretical and empirical condition for economic complexity (Hidalgo and Hausmann, 2009; Jara-Figueroa *et al.*, 2018), scientific governance and sustainable growth.

Thus, this paper focuses on the intersection of two strands of research in the field of economic and social policy; namely, innovation studies and the academic organisational and governance literature. The convergence of these topics gives insights into the ways, possibilities and limitations with which innovation can be openly driven. Innovation is subject not only to the structural capacity of actors and entities, but also to the maturity and resilience of policy frameworks. At the same time, though, openness can serve as a launchpad for innovative research structures. As such, interest lies in the identification of open transfers of knowledge and open science research practices and their symbolic or empirical influence on R&D processes and networks. We might question the strict distinction between forms of R&D (e.g., internal or external) and the implications for innovation. For instance, innovation studies have proliferated in recent years (Sun and Grimes, 2016; Lopes and de Carvalho, 2018; Sun and Cao, 2020; López-Rubio *et al.*, 2020; Sabando-Vera *et al.*, 2022). Many have focused on the overarching elements that guide the microeconomic dynamics that determine innovative processes in firms and industries (Acs *et al.*, 2017; Nguyen *et al.*, 2021; Bate *et al.*, 2023). However, more have focused on the complexities that characterise macro-level determinants of innovation (Mazzucato and Semieniuk, 2017; Laplane and Mazzucato, 2020; Deleidi and Mazzucato, 2021), whether at the sector or industry levels (Audretsch *et al.*, 2023), or from a growth-focused perspective (Dobrzanski, 2018). The abundance of literature on the topic makes it clear that innovative processes are at the centre of many narratives in academia and the public sector in general, but primarily in industry. Moreover, the coincidence of these narratives highlights the many interlinked features of these areas and their, mostly beneficial, cooperative endeavours.

Many studies focus on the links between actors (academia, public sector, and industry), whether from a triple helix outlook (van der Wouden and Rigby, 2019; Hailu, 2024) or from a framing of public policy for innovation (Picarra, 2015; Ayoub *et al.*, 2017; O’Dwyer *et al.*, 2023) and the knowledge transfer dynamics that fuel innovation in university-industry (U+I) linkages. The paper scopes discussions on the last of these. The U+I linkage also embraces the transmission of knowledge that fuses entrepreneurial activities with scientific spaces into innovative processes (Bock *et al.*, 2018; de Wit-de Vries *et al.*, 2019). Knowledge transmission leans heavily on the determinants of research network formation and research flows, as well as on the mechanisms that enable their sustainability. Furthermore, the focus on the transmission of knowledge necessarily touches upon the internal and systemic dynamics that underpin the openness of the transmission processes themselves.

Then, beyond a necessary consideration of open access, the paper will consider the open characterisation of innovation in the light of U+I linkages and collaborative developments (see Azagra-Caro *et al.*, 2022). The overview will maintain a general perspective, surveying the main qualities of innovation *vis-a-vis* open innovation (OI), primarily focused on the systemic mechanisms in place that support openness. The discussion then considers specific patterns suggested in innovation studies for a flourishing innovative environment, particularly openness and collaboration. These patterns are considered alongside key questions underlining the relevance of OI for science, industry, and the consolidation of narrativespromoting access and collaboration. Hence, the paper covers the general level of innovation studies and then focuses on the narrower scope of open innovation.

The text is then structured as follows: a first section addresses the major elements that characterise innovation and directly links them to what openness represents. A second section takes this general overview and frames it within a systemic framework, highlighting the systems of innovation approach and overarching complexity. The following section focuses on underscoring how openness operates in a system and in relation to the underlying network dynamics. Finally, the last section discusses current policy efforts at the supra-national and regional level (UNESCO and European Union, respectively) aimed at fostering and supporting OI. A concluding section re-assesses these elements and points towards possible avenues that may help develop the OI paradigm even further.

# What characterises innovation?

Innovation refers directly to the conception and introduction of novel approaches; the adapted uses of the term have come to indicate the implementation of a new perspective into an existing framework. But the applied literature of management and economic policy (see Sabando-Vera *et al.*, 2022; Zhang *et al.*, 2023) has coincided in the use of the concept as a dynamic term, one that often reflects the need to re-create and re-new the structures and relations in the production of firms and industries. Parting from the inherent role of academic endeavour - (I) teaching and (II) research -innovation has been linked to the universities’ third mission: - (III) knowledge transfer and engagement with beneficial projects (Villani *et al.*, 2017; de Wit-de Vries *et al.*, 2019;). The third mission, along with industry-driven impetus for new and attractive investments, relies predominantly on the efforts of R&D structures, which are often aligned with, or even dependent on, industry structures. Azagra-Caro *et al.* (2022), have compiled a systematic collection of contributions that touch upon the many dimensions of these dynamics.

In this sense, the U+I manifestation occurs primarily through R&D. ‘This is meant to build collaborative research initiatives that would be industry driven, with the goal of technology invention, adoption or adaptation by regional industry’ (Hailu, 2024, p.2). Applied research becomes the prime factor in the innovation framework, consisting of myriads of scientific and academic teams working in labs and institutes, many public research organisations (Finardi *et al.*, 2022). The search for insights into existing production frameworks then produces a feedback loop into the policy arena, determining the demands of industries and areas which can be coupled into the research funding allocation processes. Governments and other funding agencies then have a meaningful role to play in the innovation system, bolstering or hindering effective knowledge transmission channels (Ayoub *et al.*, 2017; Mazzucato, 2018; de Beer, 2020; Laplane and Mazzucato, 2020; Alsafran *et al.*, 2024).

These channels are also co-determined by the type of innovation pursued; for example, focused on the broad infrastructure of technology parks (Sandoval Hamón *et al.*, 2024); or assessing public-private partnerships in medical and pharmaceutical research (Yeung *et al.*, 2021). Mission-specific innovation policies are a key dimension of the innovation system as they represent the particular response to resource demanding interventions that are aimed at: a) reducing uncertainty (Bogers *et al.*, 2018; Hidalgo, 2021), and; b) better delineating product- or industry-specific complexities (Hidalgo and Hausmann, 2009; Jara-Figueroa *et al.*, 2018). In this sense, innovative dynamics are interrelated with efficiency-searching mechanisms at different levels of the production frameworks in which R&D functions, in that ‘as R&D investments ... increase, inventive output also increases’ (van der Wouden and Rigby, 2019, p.1842). Inventive potential also moves research intensive organisations towards specialisation, with which funding availability also correlates and, with it, the opportunity to pursue distinct types of innovative practices.

For instance, there are at least four types of innovation approaches, recognised by the Organisation for Economic Cooperation and Development’s (OECD) Oslo Manual (see OECD, 2009, pp.11-12); namely, organisational (as a way to re-structure productive entities in order to better serve their purpose), process-oriented (seeking cost-effective methods of production in one or all stages), product-specific (as per the introduction of an innovative product in a specific industry), and focused on marketing (looking to introduce more dynamic methods of product placement and industry presentation). These types are shaped by how differentiated or related the firms (or R&D cooperation schemes in U+I linkages) may be considering the ‘probability that countries, regions or cities enter new, diversified activities as a function of related activities already present in those territories’ (Catalán *et al.*, 2022, p.1).

How do these different forms of innovation (or innovation-based approaches) relate to the open paradigm of science and research practices? The overarching characteristic of innovation (and innovation-based approaches) is the introduction of new processes (of operation, production, design, or marketing). The re-structuring of these processes implies a sense of ontological shift in which new knowledge is adopted and/or adapted from internal R&D processes, thus adapting ‘knowledge assets outside the company ... in order to generate new ideas and bring them quickly to market’ (OECD, 2008, p.18). Only large and robust firms may be able to benefit from innovative breakthroughs, as they are the only ones able to afford the costs of research-intensive in-house operations (Wang *et al.*, 2015; Jara-Figueroa *et al.*, 2018). Smaller more dynamic firms, also benefit from external R&D processes, such as technology transfer mechanisms (e.g., through technology transfer offices (TTOs) (see Bock *et al.*, 2018, p.1378) as they can venture into adopting and adapting external knowledge (see Chen *et al.*, 2016, pp.1007-9), efficiently bypassing the associated costs with the internal processes.

Whether the above dynamic occurs in full respect of intellectual property (IP) rights (through stipulated cooperation projects or licensing agreements) or on the verge of legality (estimating the profit return *vis-a-vis* the costs of possible litigation) (see Flynn *et al.*, 2009; Tirmizi *et al.*, 2020), the dynamic itself implies that, beyond an undetermined product- and industry-specific production frontier, adoption by late comers is offset by complex learning curves. As Hidalgo (2023) argues, complex innovation is linked more closely with learning than capital accumulation as knowledge of particular processes becomes more specific. Thus, opening a firm’s R&D boundary (OECD, 2008; Chesbrough, 2019) becomes an economic necessity as it entails the possible non-survival of a firm, as well as the refinement and sophistication of an industry. The openness of firms is also dependent on their capacity to alter production trends and influence market dynamics. This is relevant at the industry level since the implementation of innovative processes tends to precede snowballing effects that, eventually, lead to industry-wide adoption of the processes (see Chesbrough, 2023).

OI, then, minimises industry-wide costs as it leads to more dynamic approaches to knowledge sharing, emphasising geospatial dynamics of collaboration and the relatedness of specialised inventiveness (van der Wouden and Rigby, 2019; Catalán *et al.*, 2022; Hidalgo, 2023). Firms may choose to license their R&D outputs, creating a vibrant exchange environment where further innovations can be developed (i.e., ‘inside-out’ innovation) (OECD, 2008; Flynn *et al.*, 2009; Yeung *et al.*, 2021). Or firms with sufficient market power can corner a market (and even an industry) by choosing to keep their innovative production processes under IP protection. Where the power of these firms is overwhelming, this approach can hinder efforts by competing firms to go around the barrier set by the dominant firm (van der Wouden and Rigby . This scenario leads to a slowdown of the entire economic sector (Mazzucato, 2018; Hidalgo, 2023). Empirical evidence on the role that IP rights have in hindering or bolstering innovation is mixed (Link *et al.*, 2019; van der Wouden and Rigby, 2019).

Firms and industries that fail to cooperate and establish more efficient production processes fail to increase their value, market share and, consequently, their relevance and position within their economic network (Hausmann *et al.*, 2014; Hidalgo, 2021). Good examples are found in the commodities markets, where international pressures keep the demand for cheap products at a certain price point from which the investment in innovative R&D alternatives becomes neither economically sensible nor desirable. This pressing dynamic is an associated factor in the so-called ‘middle income trap’ (see Das, 2016; Geginat and Saltane, 2016), where countries fail to adapt and thus mismanage the possibilities to transition to higher value processes (Fernandez Donoso, 2017; Catalán *et al.*, 2022; Lybbert and Xu, 2022). These findings are paradoxical as they contradict the corporate dictum that ‘competition drives innovation and that innovation, in turn, drives higher welfare and economic growth’ (OECD, 2023, p.4). Admittedly, even the OECD acknowledges the lack of evidence sustaining this proposition and, as with numerous empirical works, holds competition’s effects on innovation to be dependent on contextual and systemic factors.

Openness within the innovation framework, then, signifies the collaborative drive from industry-wide agents (firms and, in most cases, R&D-specific entities, mostly university-related) to exchange knowledge and streamline processes that can potentially have multiplier effects in the economy (e.g., knowledge spillovers, accelerated learning processes and strategic specialisation). Exchanging knowledge often entails firms entering into cooperative relationships with specialised R&D entities (Chen *et al.*, 2016; Villani *et al.*, 2017; Barrett *et al.*, 2021). Thus, OI means that the frontier between internal and external R&D processes becomes diffused and outdated.

## What makes innovation function as a process or a system?

The functioning of systems (social, political and economic) is a longstanding interest in the social sciences (Acemoglu *et al.*, 2005; Luhmann, 2012; Hirschi, 2018). Systems theory and its approaches highlight the elements and dynamics which determine how the system operates (Luhmann, 2012). In innovation studies, some key factors are core units within the system perspective ( Cruz Romero, 2023; Hidalgo, 2023); namely, the actors involved, their roles, the institutions responsible for the operation of supporting the internal dynamics – or those with tangential interests in internal operating relations and the knowledge flows that characterise the dynamics in place.

The systemic perspective recognises the inherent complexities of products, markets and the economy in general (Hidalgo, 2021, 2023). This means that a systemic perspective of OI acknowledges the interrelation of efforts and capabilities in the structures within the system. From this recognition, the system must activate the necessary mechanisms to facilitate an integration of the factors (Bock *et al.*, 2018; Disoska *et al.*, 2024). In other words, actors and institutions should work closely to align their objectives and integrate available resources. One way to achieve this is the facilitation of knowledge flows, whether by minimising the hurdles between U+I linkages, or by engaging in intensive sharing of R&D processes (through open licenses or other legal instruments), deepening complexity on the basis of co-location (Catalán *et al.*, 2022; Sandoval Hamón *et al.*, 2024) or relatedness (Hidalgo and Hausmann, 2009; Hidalgo, 2023).

Complexity entails a certain level of uncertainty that can be reduced by means of acknowledging and maximising existing capabilities (Bigliardi and Galati, 2016). For instance, two major dimensions of economic complexity, relatedness and concentration, can be strategically balanced in order to achieve industry-specific goals (Hidalgo and Hausmann, 2009; Hidalgo, 2023). Relatedness, on the one hand, reflects the similarity of products one sector or country produces, whereas, on the other hand, concentration reflects the level of specialisation a sector or country has in relation to other products. A product has high relatedness if, for example, many countries produce it (usually entailing low sophistication and value added, thus low entry costs). Correspondingly, a product is highly concentrated if few countries produce it (signalling high entry costs and knowledge requirements). Economic sectors and countries, in general, then have the challenging task of offsetting their competitive advantages and seeking to innovate processes that can transform their industry’s complexity.

This may encounter at least two obstacles; namely, absorbing the knowledge within the system (i.e., implementing or integrating R&D processes) (Sun and Grimes, 2016; López-Rubio *et al.*, 2020, 2022), and the delicate problem of intellectual property (IP) protection (Catalán *et al.*, 2022; Lybbert and Xu, 2022). These processes usually occur simultaneously through dynamic absorption of existing capabilities (Acs *et al.*, 2017; Directorate-General for Research and Innovation (European Commission), 2021; European Commission, nd a). The balance between implementing R&D infrastructure and adopting/adapting existing research tends to be determined by expectations on the returns from employing innovative processes. Expectations can be influenced by the foreseeable costs of licensing, patenting and/or enforcing IP. Conversely, competing firms may also encounter the trade-off between following IP conventions or circumventing them and paying compensation. If the expected payout is large enough, many firms may find the latter scenario more attractive.

# How do innovation systems relate to openness?

OI systems create environments suited to effective collaboration and exchange, facilitating the transmission of knowledge and lowering R&D costs. These exchanges must engage with dynamic processes of capacity absorption, creating the conditions for actors and institutions to foster vibrant relationships. The underlying relationships between the actors and institutions in the systems determine how open and how successful an innovation and R&D environment can be. In this sense, ‘what matters for academic patents to improve firms’ economic performance both at short and at long term is ... the stock of technical and scientific knowledge on which inventions are based’ (Cerulli *et al.*, 2022, p.25). Institutions can then provide the financial and material infrastructure, as well as the legal background needed to promote complex and dynamic productive processes. Actors, however, make use of these instruments to engage in processes of development or adoption of processes that may lead to system shifts, building on the collected expertise that has been developed previously.

Flows of knowledge, and the mechanisms supporting them, should be managed and configured in a such way that they become part of the necessary conditions for innovation. The flows can effectively ‘be implemented with a wide range of external stakeholders’ (Bez and Le Roy, 2023, p.237), encouraging otherwise competitive actors to collaborate. Collaboration, in the end, is subject only to requirements for transformation - from both the actors’ and institutions’ perspectives (Audretsch and Feldman, 2004). A key factor characterising the limits of transformative potential is the capacity to translate endogenous and exogenous resources (investment capital) into profit-generating operations (Ayoub *et al.*, 2017; Camilleri *et al.*, 2023). This supposes acknowledging the differences between public and private funding sources, and the respective determinants they impose on innovation development. These impositions are, in similar manner, also influenced by the level of precision and singularity of funding schemes.

Oopenness relates to the main component of innovation systems; namely, collaboration. Open innovation is nurtured by exogenous and endogenous R&D processes that complement each other, at times even supplementing one another. The core of open innovation is found at the capability level of each actor (and of the institutional framework around them) to assimilate novel processes. A neo-Schumpeterian approach (Deleidi and Mazzucato, 2021) recognises this determinant and accentuates the role of the state as a facilitator of innovation (Stodden, 2010; Bogers *et al.*, 2018). Absorption and assimilation processes then occur within channels created for with the specific purpose of facilitating linkages and networks, thus expanding the value chain of industries and/or products (Hidalgo, 2023). Firms may also find themselves in positions to adapt strategically to competing interests, minimising costs while maintaining a competitive advantage. Bez and Le Roy call this ‘coopetitive open innovation’. However, the strategy must embrace the specificities of markets, products and policies (OECD, 2009, 2023; Mazzucatto, 2018; Hidalgo, 2021, 2023) to avoid encountering bottlenecks in supply.

Open innovation is a cross-cutting factor in innovative dynamics. The literature commonly refers to ‘outside-in’ or ‘inbound’ innovation (e.g., Wang *et al.*, 2015). The logic is that innovation within an open system can be absorbed and assimilated by firms within the system, regardless of their participation in R&D (e.g., Nguyen *et al.*, 2021). ‘Inside-out’ or ‘outbound’ innovation has been less studied (Lopes and de Carvalho, 2018), probably because it requires highly-detailed observation of how firms move according to market and investment opportunities. Outbound innovation also implies sufficient capacity of firms to manoeuvre and decide whether to release R&D outputs which might lead to innovative adoption by other firms, taking advantage of potential social and economic networks (Lopes and de Carvalho, 2018; Bez and Le Roy, 2024). However, outbound assimilation also reflects how a truly open system can benefit from an efficient allocation of R&D resources whereby smaller firms may release a prototype in the expectation that another firm may streamline it. The same holds for processes within U+I partnerships. On a larger scale (larger as a measure of firm size), firms may opt for licensing their processes and consolidating market and cooperation strategies.

## How do actors engage in open innovation?

In the case of U+I agreements, these is one common way in which actors engage within an open system of innovation. Institutional arrangements are usually in place to facilitate: a) the availability of research funding (Acs *et al.*, 2017; Disoska *et al.*, 2024) and b) the transfer of research outputs into economically-oriented products and processes (Ayoub *et al.*, 2017; Sabando-Vera *et al.*, 2022; Sandoval Hamón *et al.*, 2024). The former is dictated nationally (as in the German Research Foundation’s (DFG) guidelines) or even regionally (as in the European Commission’s declarations regarding open science).[[1]](#footnote-1) The latter implies links with external actors with ample funding and investment possibilities, usually in the form of venture capital funds (VCFs) (Wang *et al.*, 2015; Villani *et al.*, 2017; Bock *et al.*, 2018). VCFs are common in the United States, but less so in Europe, given the regulatory framework in place (European Commission, nd.a, 2020). VCFs offer ample opportunities for dynamic change, whereas direct funding from public agencies offers more stability in the R&D process (Mazzucato and Semieniuk, 2017). Publicly-funded R&D is also subject to less competitive pressure to deliver patentable or licensable outputs, but is better suited to cooperative and collaborative processes.

Nonetheless, start-ups with VCF backing or non-publicly funded start-ups have a higher level of profitability and operational dynamic (Ayoub *et al.*, 2017; Laplane and Mazzucato, 2020; Link *et al.*, 2019). In other words, there is a higher rate of knowledge transmission into profit generating operations; whereas university-based start-ups, typically relying on public funds, operate with higher levels of overhead and lower profit generation (Ayoub *et al.*, 2017; Link *et al.*, 2019). This very distinction in the way innovative firms operate is reflective of the many dimensions in which open innovation is achieved. For instance, one of the main characteristics of collaborative enterprises is the exploration of processes (see Zhang *et al.*, 2023). Exploration is determined mainly by the intensity of the research environment and the resources available. Exploration is also in line with ‘coopetitive’ open innovation (Bez and Le Roy, 2024), reflecting the incentive structures that larger firms, for instance, may have compared with smaller ones in terms of operational schemes. In addition, exploration is strongly associated with academic contexts in universities and research institutes where open science practices are standard.

The U+I linkage stretches beyond the limited exploration possibilities that academic entities offer firms. In most cases, such relationships are formalised through cooperation agreements that regulate the extent to which research entities may profit from innovative research, as well as the extent to which firms may be involved in providing research entities with material and structural support (Mazzucato, 2018). The European situation is different from the American in the level of integration firms may have within the university structures. European academic research entities enjoy direct channels with key firms in diverse industries, allowing direct placement of graduates and researchers, as well as access to tools and laboratories. The competitive dimension of innovation is turned inwards as attracting highly qualified talent becomes the starting point for ‘coopetitive’ behaviour.

The European Commission has regulated the extent to which open science may be subject to actual open standards (European Commission, n.d., a; 2020; Directorate-General for Research and Innovation, 2021) in what might be considered a concession to market dynamics. In a clear nudge to the cross-cutting R&D processes, the Commission has noted that publicly-funded research must be ‘as open as possible’ but ‘as closed as necessary’ in order to function in accordance with IP requirements arising from funded research ( UNESCO, 2023; UNESCO and Canadian National Commission for UNESCO, 2022). The obvious exceptions are biomedical and pharmaceutical research and the underlying data that serve as the basis for the development of treatments and/or drugs.[[2]](#footnote-2) These fields came with their own set of protocols and rules for experiments and randomised controlled trials. Biomedical innovation R&D provides a vibrant example of the possibilities and limits of OI as ethical considerations are directly entwined with commercial interests.

The latter has important considerations for the underlying market structures that determine cooperation or collaboration; i.e., competition and market share. An optimistic perspective acknowledges that ‘sound competition policy that creates a level playing field, facilitates the entry of new players into markets and the introduction of new products and processes’ (OECD, 2023, p.5). Yet, innovation may deter firms (and R&D entities) from collaborating, seeking to maximise financial return to the detriment of strategic return. In open environments, many U+I linkages occur because of this logic in the form of spin-offs (Ayoub *et al.*, 2017; Bock *et al.*, 2018; Bez and Le Roy, 2023). Such organisational structures can bypass IP frameworks and provide a way to couple financial and strategic goals. They encourage innovative research, though they hinder competition as a result of the highly specialised, unrelated R&D they carry out (Hidalgo, 2023). Similarly, closely-linked spin-offs may converge into start-ups, which may then turn into solid independent firms. This dynamic is fuelled by knowledge exchange and proximity (e.g., Audretsch and Feldman, 2004; López-Rubio *et al.*, 2020; Tirmizi *et al.*, 2020). Thus, knowledge channels represent another dimension of the limits of openness and the need for closedness.

The potential for effective knowledge diffusion in scientific systems is therefore co-determined by the structure of incentives in place that enable collaboration and U+I initiatives (e.g., increase complexity, manage collaboration partners, streamline internal operations etc.). Some fields of science have greater hurdles to manage, making the transmission of knowledge a highly mediated dynamic. This mediation is characterised by interacting elements in each of the dimensions of innovation systems. Put another way, the amount of friction amongst actors, mainly funders and R&D units, determines the flows of knowledge between the R&D entities and a) established firms seeking novel approaches, and b) dynamic start-ups seeking to disrupt processes of production. However, the latter distinction generalises the role of smaller firms. Disruption (a broader consequence of innovation) does not necessarily depend on the size of organisations, but rather on their operational agility. Inside-out and outside-in then become a matter of financial stakes rather than strategic outlook. Competition, as the OECD (2023) points out, is often overlooked and underestimated, as it could deter and hinder collaboration and open innovation frameworks.

The agility to adapt and adopt novel processes is based on the capabilities developed by firms to absorb knowledge from a system in constant change. Whether through direct channels agreed on commercial terms, or through indirect, more porous ways that exploit the open nature of the system, R&D linkages drive the OI system and environment. One further question that fits this approach relates to the institutional backdrop. This is one of the key underpinnings of OI. The European Commission’s science policy framework can serve as an example in this regard.

## What policies are in place to support open innovation?

The uptake in open science practices - open access being the most obvious - has been partly driven by policy-enacting organisations (UNESCO, EU, DFG, for instance), but is also a response to academic trends. Again, the biomedical and pharmaceutical cases stand out as paradigmatic as regulatory frameworks are constantly changing (Wallach *et al.*, 2018; Schniedermann, 2022). The same has applied in recent years in computer sciences, engineering and artificial intelligence (AI) (Acs *et al.*, 2017; O’Dwyer *et al.*, 2023). The ethical use of open (and license-restricted) data, as well as the use of AI in research, have come under close scrutiny from funding and regulatory agencies (UNESCO, 2021; UNESCO and Canadian National Commission, 2022).

Regulatory and policy efforts have been directed at assuring that the structural conditions necessary to guide scientific efforts within innovation-based environments are in place, and that rules and norms needed for compliance with both open science standards and firm-oriented processes are in place. The regulatory framework has now been extended to include sustainability, which, because of the ever-increasing requirements of computational resources, imposes a considerable burden on transitioning industries (Lippolis *et al.*, 2023). This economic transition presents both challenge and opportunity for firms and research entities to develop solutions for agricultural and climate-oriented problems (Burkhard *et al.*, 2016). In these fields, OI has great potential to serve as a conduit for societal solutions by implementing novel technological processes.

Policymakers have set their sights on the expansion of open science goals in broader terms, as well as in more specific elements that pertain to investment in infrastructure (European Commission, nd, a, b). The European Commission, following UNESCO’s open science guidelines, has been funding open science infrastructure as a priority. This includes funding everything from open repositories (to host and preserve open data from research projects) to article processing charges (APCs). Guidelines from both organisations call for a broadening of the scope of funding and support to establish open infrastructure (laboratories, hardware, and research centres) as a new baseline for open science (e.g., De Maria *et al.*, 2020). The outcomes are not explicitly defined, nor precisely described; open infrastructure requires investment and maintenance, elements neglected in policy discussion.

Policymakers must acknowledge openness as central to R&D with the potential to yield returns in key areas (e,g., education, technology, environment). Thus, as the Commission notes, open science schemes must address the linkages between research and innovative actors, strengthening the U+I channels that advance the innovation economy. It is no surprise that the Commission’s policy guidelines are focused on innovation as crucial for driving education and growth in the region (European Commission, 2020). This approach relates to the bloc, but with specific recognition of the Swiss and the British (notwithstanding the UK’s departure from the EU). From this policy perspective, innovation is expected to supplement existing channels linking firms and university research. Research funding favours research that replicates previous research programmes rather than anything innovative.

The fundamental factor driving innovation-based policies is the applicability of goals. Funding goes to areas where it will have the most tangible impact; for instance, health, food and environmental security (Burkhard *et al.*, 2016; Lippolis *et al.*, 2023). Yet, both theoretical and applied research are key contributors to innovation. Highly-theoretical fields can contribute their expertise to highly-applied topics, as is seen in Physics, Mathematics and Chemistry (Aziz *et al.*, 2020; Le *et al.*, 2019). Moreover, the humanities are also a source of innovation-oriented research, linking elements of technology and natural sciences in order to offer novel approaches to market-oriented processes and products ( Lopes and de Carvalho, 2018; Le *et al.*, 2019; Aziz *et al.*, 2020).

Funding schemes pushing open science and the OI framework should look for collaboration in large-scale research projects to bring together expertise from a range of areas. The applicability of OI guidelines and policies is dependent on the extent to which specific know-how can be linked and directed. In many cases, this dynamic (re-)creates knowledge networks that expand beyond disciplinary boundaries. From an OI perspective, the participation of various actors and organisations permits a more dynamic flow of information, facilitating not only the initial objective, but potentially giving way to secondary research goals that may have ‘spilled over’ during the intended R&D process. Within this R&D process, particularly when large, multi and interdisciplinary teams are involved, uncertainty is characteristic of attempts to convert fundamental or basic research into applied innovation (Frankfort and Hagedoorn, 2023). Uncertainty in the management of innovation is closely linked with legal frameworks at the U+I level (Hidalgo, 2023). More precisely, from the legal perspective, IP rights and regulations are the basic elements that facilitate or hinder the management of open innovation.

# Final remarks: trends and challenges

The ways in which openness engages with innovation are co-dependent on myriad factors that involve actors and networks, from policymakers to VCFs, and from researchers to data managers. Innovation-promoting policies are at the heart of the regulatory ambitions of many firms, industries, and nations. These policies align, in most cases, with the desire of the science system to pursue openness, from research design protocols to knowledge transfer mechanisms. This, in turn, aligns with specific narratives of scientific practices that may appear open, but which nonetheless include a number of opaque elements.

Practical and mission-oriented policy needs to address the externalities created by uncertain innovation processes. The goal of policy needs to be in line with those of research facilities to maximise benefits from R&D. The narrative of openness must, therefore, attend to the scientific and academic, as well as to the market. Legally securing the innovation environment helps reduce uncertainty and gives researchers the stability to pursue novel topics.

The study of the many dimensions of OI opens up the possibility of interdisciplinary work involving knowledge-creation, as well as transfer and marketisation mechanisms. Attention to regulation is particularly important. Innovation practices (in particular, open innovation practices) are constantly shifting, demanding swift and flexible policy. As de Jong *et al.* (2016, p.103) argue, ‘scientists are able to cope with new policies by selectively complying or not complying and because of the existence of additional sets of professional rules’ (that is, peer legitimacy processes). And in line with broader societal impact debates (Fecher and Hebing, 2021), ‘academic researchers can find it difficult to deal with the tensions and contradictions between these logics’ (Llopis *et al.*, 2022, p.9). The logics in question are the so-called ‘hybrid’ logics, referring to the convergence of demands by academic and policy managers, oriented at increasing both the societal and thecommercial impact of research.

Fecher and Hebing (2021) argue that imprecision in the meaning of societal impact may lead to incorrect assessment of the true benefits of research. Future research along this line may well focus on intersections with, for example, citizen science and the effects of non-academic actors in innovation processes. UNESCO’s policies recognise these individuals and groups as relevant actors in a societal layer of research, highlighting their role in consolidating ‘open engagement’ in science, as well as in ‘public creation of scientific knowledge’ (2023, p.28). Yet, OI practices and policies face the challenge of striking a balance between the incorporation and oversight of external parties in R&D and undesirable secrecy in the organisation.

Both firms and research organisations face similar constraints in terms of how they engage in cooperation agreements (Finardi *et al.*, 2022). There are at least two problems: a) the physical distance, or geospatial limitation (Villani *et al.*, 2017; van der Wouden and Rigby, 2019) and b) firm- or industry-specific constraints regarding expansion possibilities and/or competitiveness levels (Jara-Figueroa *et al.*, 2018; Zhang *et al.*, 2023). Geospatial limitation can be overcome by means of digital media, as well as information and communication technologies (in open repositories with open digital infrastructures). If physical proximity remains a necessary condition, as with special infrastructure (laboratories, materials or trial settings), collaborative innovation may be hindered by slower communication. Immediacy is especially valuable for innovation systems.

When firms are unable to collaborate with other firms or with research entities, they may consider stimulating mobility processes; that is, exchanging expertise in a narrower sense. The intensification of cognitive mobility emphasises knowledge transmission links that enables efficient sharing of research, bridging the divide that separates academia from the private sector. In an OI system, the set of incentives offered by firms should complement existing structures in research entities in order to harmonise research tasks and knowledge transfer.

OI research would benefit from more pragmatic approach to innovation systems. In most cases, interest is in a high level contexts where policy is clear and governance structures are in place (Acs *et al.*, 2017; Alsafran *et al.*, 2024). Few approaches deal with direct incentives in U+I partnerships (i.e., the underlying conditions that motivate firms to engage in collaborative R&D). It also remains a challenge to identify the motivation underpinning licensing of IP (i.e., what motivates universities and firms to enter IP-protected R&D collaboration). Research on open innovation practices can expand beyond policy. Fields such as Sociology, and Management Studies can contribute to a comprehensive analysis of how, where and when (naturally also, why) researchers and firms choose to cooperate in innovation. The many aspects of these issues help explain the underdevelopment of OI as a cohesive field of study that encompasses technology and engineering areas, as well as the social sciences and humanities.

For instance, one of the outstanding aspects of innovation research is the availability of data - high resolution data, more precisely (Lybbert and Xu, 2022). It can be argued that, in some approaches to innovation, such as the innovation-expanded economic complexity index (Hidalgo and Hausmann, 2009; Hausmann *et al.*, 2014), granularity is one of the key attractions. Indeed, the index is one of the most fine-grained approaches, though it is limited in the scope of its analysis (Hidalgo, 2021, 2023). For most other studies working with time series and/or cross sectional data, the limitation is compounded by the usual shortcomings of statistical designs (e.g., omitted variable biases and autocorrelation of the variables). OI, both as a field of study and as a science paradigm, can contribute to the diversification of available databases and to the overall availability of more and broader data. Open research data would integrate knowledge transmission and diffusion channels more dynamically. Open repositories in research teams with open science protocols are already a reality. However, the broadening of this approach to the entire system (or even parts of it) could encourage the consolidation of open science and OI.

Open research data would benefit both industry and academia; the former from dynamic data flows and knowledge transmission (cognitive and geographic mobility), and the latter from in-depth data sources. Large open data sources contribute to the analysis of the topic, on the one hand, and also serve as a basis for policy formulation to help develop OI, on the other hand. Innovation studies must also take account of structural and systemic differences (both intra-regional and international). Such differences affect the way access and collaboration are framed and practiced. Addressing these issues can also aid understanding of the structural and causal mechanisms underlying OI and open science. Innovation is a complex phenomenon; openness can contribute to the understanding needed to push the boundaries of creativity.

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1. For instance, the [German Research Foundation](https://www.dfg.de/foerderung/info_wissenschaft/2022/info_wissenschaft_22_61/index.html) has announced a shift in its evaluation procedures in which qualitative aspects, such as open science practices, will be at the core of assessment. The [European Commission](https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/commission-signs-agreement-reforming-research-assessment-and-endorses-san-francisco-declaration-2022-11-08_en) has taken similar steps to reform. [↑](#footnote-ref-1)
2. Other less visible exceptions relate to art, where licensed work may be protected by IP rights (e.g., music, film, or photographs) and some social science and humanities subfields, where indigenous knowledge has gained legal recognition. [↑](#footnote-ref-2)