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For many years the transfer, exchange and collaboration of knowledge and technology between academia and industry have been discussed as an important means of generating commercial value. The underlying rationale for such collaborations is that knowledge and technology from academia lead to firms' competitive advantage. What has received less attention in the literature, so far, is a science-based collaborative approach for addressing societal challenges. In particular, we focus on collaborations among different actors - ranging from academics, businesses, policy makers, intermediaries and society - who devote shared resources, competences and capabilities in developing unique solutions to economic and societal challenges. The specific domain of a such process - that demands thinking beyond the knowledge transfer or creation expected to produce business value - is framed as "co-creation". This paper outlines a conceptual framework by capturing the heterogeneity of science-based co-creation and its determinants. In the paper, the concept of co-creation is positioned in the various strands of innovation literature which refer to collaboration across different domains, highlighting the uniqueness of co-creation. We suggest focussing on a distinctive character of co-creation: the production of both business value and social values that emerges with different forms of innovation, reach and prominence. While business value has its own metric in a monetary scale, when society is considered, metrics should refer to the many different dimensions that have been impacted on, leading to many social values (in plural). The paper highlights research gaps to further our knowledge on co-creation and suggests policy implications to support effective mutual interactions across science, technology and society.

JEL Codes: O14, O31, O33, O38

Keywords: RnD collaboration, Co-creation, Industry-Science Linkages, University-Industry Collaboration, Triple Helix, Knowledge Triangle

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1. Introduction

In the debate about the application and use of science, the early focus has been on knowledge or technology transfer, frequently assuming (more or less explicitly) a linear innovation process. In line with the emergence and widespread acceptance of the open innovation paradigm, collaborative innovation related activities have achieved considerable popularity involving all stages of the innovation process. During the early development of this framework, openness was often understood as incorporating external inputs to company's innovation projects. Similarly, the literature on innovation has extensively discussed the economic value generated by the interaction between actors in innovation projects, and especially the literature on the knowledge intensive business services (KIBS) has focused on the economic importance of customer orientation for product and service development (Jones et al 2013; Chesbrough and Di Minin 2014). Building on these developments, the recent literature seems to focus on many diverse types of collaborative activities, including 'co-creation'. Co-creation during its initial developments is perceived as an innovation management tool for service industries by means of customer involvement in product/service design (Adner and Kapoor 2010; Gemser and Perks 2015; Hienerth et al 2014; Miles et al. 2017; Perks et al. 2012). Others extend the customer involvement dimension towards broader company affiliations with organisations in an array of different domains, such as businesses, universities, government, intermediaries and society (Jones et al 2013; Chesbrough and Di Minin 2014) with the aim to simultaneously generate business value and social values (Fuchs and Schreier 2011; Grimaldi and Grandi 2005; Levine and Prietula 2014; De Silva and Wright 2019). Yet, there has been little emphasis on science-based co-creation between individuals from different organisations aimed at increasing the use of science, which simultaneously generate value for business and society. The latter is clearly a significant policy interest, especially in relation to policies that target social value creation by enhancing the interaction between science and economy in a broadest sense (OECD 2017a, OECD 2017b). Against this backdrop, we develop a conceptual framework capturing the heterogeneity of science-based co-creation and its determinants. We define science-based co-creation as *a collaborative approach by actors associated with different organisations – including universities, businesses, government, intermediaries and society - who devote shared assets to simultaneously generate social values and business value across science, technology and society, which a single party is unable to deliver independently.*

The significance of co-creation is then not so much the interaction dimension *per se*, as the mechanisms and specific factors affecting the process of the simultaneous creation of business value and social values is a joint effort of independent interacting actors, aligned in sharing a goal, and contributing with their own specific resources, which also require a revised policy agenda (Meissner et al 2017, Russo 2000). With regard to society, the many social values matter when taking into account the outcome of the innovation process. Values, in plural, reminds us the different perspectives in assessing business and social impact of any action (see Stark 2017) and of innovation, in particular.

This report initially briefly recalls the streams of literature related to collaboration in innovation processes in order to highlight the uniqueness of science-based co-creation. Then, section 3 presents a conceptual framework on co-creation, by focusing on the nature of value co-created, the specific inputs to co-creation provided by various actors involved in such process of interaction, the intentional dimension in being engaged in co-creation, the potential impact of external factors in influencing the co-creation process. Finally, section 4 highlights the rationale for innovation policies supporting co-creation processes.

2. Positioning of science-based co-creation in related streams of literature

The debate about linking science and application has taken many forms during the past decades. However, this has frequently referred to as the transfer of technology and knowledge which is a much-simplified understanding assuming that innovation occurs in a linear process model. Even the advent of the open innovation paradigm in the early 2000s didn't change much in this thinking, although it stresses openness and collaborative activities. Given this background, significant literature emerged highlighting open innovation, clusters, Triple Helix / Knowledge Triangle / Quadruple Helix, Innovation Systems and R&D collaborations. Table 1 compares and contrasts the key features of these literatures alongside those of co-creation with regard to the units and the level of analysis, the outcome of interaction streams, the dominant nature of interaction, the prominent type of value generation. As clearly evident in this table, the conceptualization of science-based co-creation, in comparison to other related domains of literature, provides an opportunity to enhance our knowledge on interactions between: (a) individuals associated with different organizations, (b) who devote and integrate complementary assets to (c) simultaneously generate social values and business value across science, technology and society, which a single party is unable to deliver independently.

Table 1: The significance of collaboration in science-industry relations

Streams in the literature	Units of Analysis	Level of analysis of the outcome of interaction streams	Dominant nature of interaction	Prominent type of value generation
Industrial Districts Brusco 1982; Becattini,. 2002; Russo 1985	System of companies in the district	System (industrial district) performance	User-produce interactions and industry-science interactions fostering innovation processes. Ad hoc created organisation (service cen-ters/intermediaries) facilitate interactions	Reputation, trust, network effects and spillovers. Maintaining the dynamics of community values that support the economic values
Innovation Systems Mowery & Oxley, 1995; Nelson 1993, Edquist 1997; Lundvall 1992	Institutions such as universities, government, business	The nation or region affected by the systemic interactions	One organisation producing an output for another Government as facilitator	A country's (or region's) innovative performance
Industry-Science Linkages; University-Industry Relationships OECD 2003	Universities and Research Institutes	Impact of organizations on economy	Spillovers from public research	Regional and national innovation performance
Clusters Porter 1998	Groups of organisations (e.g. localized supply chains)	The units directly involved in the cluster vs. the local system in industrial districts literature	Business-business, industry-science interactions Ad hoc created organisation (e.g. cluster organizations) involved in supporting this interaction	Mainly economic value for regional development
Open Innovation Chesbrough 2006; Enkel, et al. 2009, van de Vrande et al. 2009.	Firm, projects, and teams	The units directly involved in the process	A wide array of interactions, including knowledge transfer, exchange and co-creation	Mainly business value
Triple Helix/Knowledge Triangle/Quadruple Helix Etzkowitz e Leydesdorff 2000; Carayannis and Campbell 2012;	Institutional spheres of university, industry and government and their interactions	The units directly involved in the process	Dynamic interactions between institutions, with University at the core. Framework conditions for research institutions and universities are set by governments	University's and science contribution to socio-economic development

Gokhberg and Meissner, 2013; Oecd 2017a, 2017b				
R&D Collaboration Vonortas 2011; Katz and Marint 1997; Cunningham and Link 2015	Collaboration between science and industry	Organisations directly involved in the process and the network generated by their interactions	Research and development-based interactions, often with contract research-based focus	Joint innovation
Co-creation Jones et al. 2013; Chesbrough and Di Minin 2014; Levine and Prietula 2014; De Silva and Wright 2019	Individuals (who may be affiliated with different institutions and organisations) and organisations	The network directly involved in the process (both individual and organisations) and the related societal domains affected by spillover effects	Close interactions between organisations and individuals – through the integrations of their assets – in order to achieve a common goal under a given institutional framework	Value for all the parties involved ranging from business to academic and social values

Source: authors elaboration

3. Conceptual framework for science-based co-creation

In co-creation, individuals and not just organisations are co-players, working together closely. These individuals might be associated with different organisations including those with both for-profit and not-for-profit motives. They decide to work together closely - sometimes by creating separate and independent (i.e. independent of actors' organisational associations) social or physical structures (e.g. accelerators, social labs and living labs, etc.). These individuals integrate different assets - including knowledge, resources and networks (i.e. in comparison to knowledge transfer and exchange that are aimed at acquisition rather than integration) - to achieve common goals (De Silva and Rossi 2018). Their differences (in terms of expertise, attributions or access to particular agents or artifacts) and aligned directedness (in having a common goal to achieve through co-creation) are preliminary conditions for a generative relationship (Lane and Maxfield 1997). Their mutual directedness is reinforced by recurring patterns of interaction, by opportunities of being engaged in joint activities and by appropriate permissions for alignment.

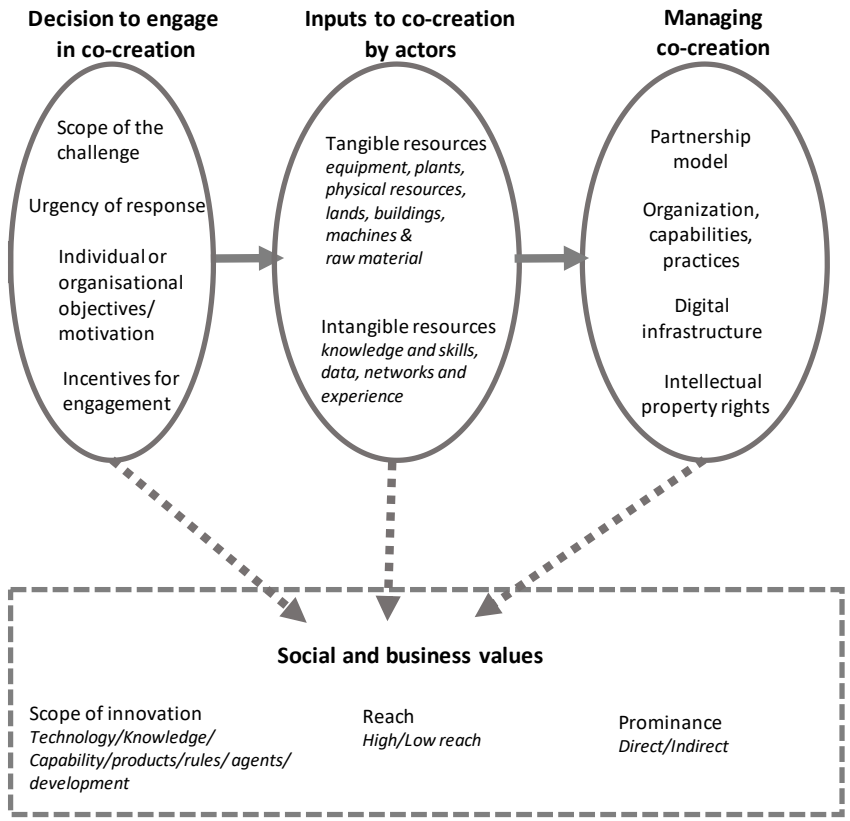
Hence, co-creation requires a close working relationship 'ideally' from the beginning of the process, and a careful thinking by partners on which assets to be integrated and how (De Silva and Wright 2019). Hence, the conceptualization of co-creation places a greater emphasis on the decisions on the relationship between assets and outcomes, mechanisms to integrate assets, and intellectual property rights associated with the use of assets etc. A close working relationship between 'individuals' from different organisations to simultaneously generate both social and business value could be challenging due to the need to couple competing and potential conflicting goals, behaviours and practices (Pache and Saton 2013; Ebrahim et al 2014). Thus, incentives, micro-foundations of capabilities and skills, leadership, motivation, commitment, and relationship building and management on the achievement of competing social and business value through close interactions are core determinants.

Joint identification of specific opportunities entails parties creating and shaping the specific aspects of the opportunity in order to ensure that it has the capability to meet their objectives, which is important to ensure commitment of each other. These opportunities integrate social and business dimensions and are co-exploited by actors through multiple channels that involve the execution of operational level strategies to integrate their complementary assets.

To fully outline the conceptual framework that would enable analysing co-creation mechanisms, it is necessary to make explicit the heterogeneity of its underlying mechanisms and to single out how to enhance their effectiveness in achieving specific organisational/individual objectives, which would in turn improve our understanding of government and policy support required for co-creation success.

Three types of conditions are critical in determining the nature of social and business value generated, summarised in Figure 1.

Figure 1: Determinants and outcome of a co-creation project



Source: authors' elaboration

First, the criteria used to make the decision to engage in co-creation (as opposed to other forms of innovation/value creation such as internal R&D, knowledge transfer and knowledge exchange) would influence the nature and role of actors involved in a specific initiative, which in turn would influence the nature of value co-created. Co-creation should not be considered as a substitute of internal R&D activities or other forms of collaboration such as knowledge transfer or exchange. Organisations should carefully make the decision as to the objectives to be achieved through co-creation and those that should be achieved through other forms of engagement (De Silva and Wright 2019). Among different aspects that would influence this decision, we have identified four key factors, namely: scope of the challenge addressed; urgency of response required; objectives/motivation of organisations and individuals associated, and incentives for engagement in co-creation. Until recently only little is known and evident about how these different factors are interrelated with the nature of value co-created.

Second, on the basis of actors' reasons for engagement in co-creation, the needs of the initiative as well as each party's individual resources, actors would provide differential input, the integration of which would be required to generate value. Resources are anything an actor can draw on for support (Vargo and Lusch 2004), which include both tangible resources, and intangible resources. The strategies adopted and decisions made in relation to the resources to be integrated during co-creation would in turn will influence the nature of value co-created, our understand of which is significantly lacking.

Third, we also highlight key factors that would influence the co-creation process and its success. For the successful implementation, common interests and complementary skills are a key prerequisite. Four main overarching key factors emerge as influential for the success: partnership model; co-creation practices and capabilities; digital infrastructures and intellectual property rights. While these factors would influence any form of collaboration, what we need to further our understanding of is their influence on the nature of value co-created.

Having outlined the main determinants and mechanisms affecting co-creation has paved the way of addressing the most significant feature of co-creation: the dual value creation. In this context, 'value' means gains – in the form of business and social benefits – by parties collaborating as well as their key stakeholders (i.e. to whom parties intend to generate value), the generation of which is not possible by working independently. Such value involves addressing challenges of both commercial and social value, such as reducing poverty, developing drugs for neglected diseases in developing word, improving public health, reducing skill gaps, reducing environmental pollution, improving environmental sustainability and addressing the challenges of the aging population. While co-creation initiatives would simultaneously generate social and business value, these would be multidimensional, in terms of specific objectives and previous conditions of the interacting agents, objectives of the co-creation, beneficiaries of the created values and roundaboutness of the value creation. Three main dimensions characterize the nature of value created: its scope (innovation, technology/knowledge development or capability development, products, agents or rules might emerge); the reach (benefiting a focused or a broader group); its prominence (direct or indirect value). Beyond the direct linkages among the determinants and the outcome of a co-creation project (the arrows in Figure 1), several feedback loops may occur even within a single project (i.e. as a result of on-going and final evaluations), not to mention the ones that together with learning effects might be induced by the process activated by co-creation at a larger scale. The dotted lines in the figure highlight the mechanisms that should be further analysed in their impacting on the creation of business and social values.

4. Discussion and conclusions: the rationale for public policy supporting co-creation

Co-creation is an interaction model in which networks and partnerships act as catalysts while other spill overs of industry-related partners or other research centers in the network flow easily into the company's own innovation ecosystem. This process shows a significant potential for inter-disciplinary research and the timely conversion of research results into applications as well as the vitalization of regional networks with national and international outreach. It supports the building of trust between the partners, reduces the widespread free-rider problem and allows a sustainable use of competences to be mutually developed. The bundling of resources and the institutional cooperation allow for the targeted exchange and inspiration between basic and applied R&D and the resulting synergies. One important precondition is the legal status of the institution which is essential for trust building and open exchange between the partners.

Co-creation potentially becomes a Science, Technology and Innovation (STI) policy instrument that complements supply-driven policy instruments especially aimed at enhancing Knowledge and Technology Transfer (KTT) and developing absorptive capacities.

One significant barrier for establishing sustainable co-creation are the high transaction costs occurring in their early stages. Moreover, the rather short-term focus of companies poses a risk that synergies will not be fully developed and exploited due to the tendency of companies to employ controlling mechanisms in co-creation, which are to some extent counterproductive to the long term nature of building and using synergies.

Yet, the increased emphasis on co-creation initiatives in recent years as well as its uniqueness in dual value creation, compared to other forms of interactions, have intensified the need for new STI policies in taking an ecosystem perspective to support joint activities as a strategy to generate social and business value. While public policy actions introduced in recent years have made a great contribution to this emerging emphasis on encouraging and supporting collaboration, yet, more needs to be done to facilitate different forms of co-creation style initiatives. This is mainly because a one-size-fits-all STI policy for heterogeneous co-creation mechanisms seems unlikely to work since these types generate varied societal (including academic) and business impacts by adopting different mechanisms. Thus, the STI policy intervention needs to promote the cooperation of the various subsystems and all eligible players, namely research institutes, universities, small and large business, intermediaries, local and regional communities and associations. Therefore, co-creation oriented STI policies are less targeting on direct financial support but more on the framework design thus providing conditions allowing public organisations and public sector employees engaging in co-creation but also providing clear conditions regarding all related legal aspects. In addition, evaluation criteria of such policies should be carefully defined, with a focus on the systemic and longer term impact and behavioural additionality they are aimed at.

Such policy framework has to carefully integrate specific measures for managing universities and research institutes in empowering people working in public organisations for being engaged in co-creation processes. Accordingly, it is needed to design a coherent framework of performance evaluation and incentives in public research and academia.

In such framework, it is clear that international STI collaboration might play a key role in co-creation for addressing global challenges. But this calls for co-creation at a broader scale and implies that national and regional policies should be designed to making co-creation possible. Although largely advocated by national policies, there still remains a clear weakness in globally agreed performance measurement schemes which expect each country's individual contribution in addressing Sustainable Developmental Goals (SDG). Performance measurement schemes are still mainly aiming at detecting impact on local, regional and national ecosystems, with no consideration on the need of international level co-creation to address global challenges. If the scope of co-creation involves global challenges, national egoisms need to step back and a strong support throughout the activity by political means is needed. This involves an agreed agenda between different national and regional policy makers at different levels: experience from responses to SDGs shows that global political commitment is supportive of co-creation but more need to be done to implement related activities. The reasons why there is little progress on the SDGs related policies are manifold, including strong competition of national research systems around the world, rather than attempting to co-create dual value to address global economic and societal challenges. The current joint international effort on STI under the Covid-19 pandemic might pave the way for a new strand of international co-creation initiatives addressing global challenges.

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