A framework to characterize multi-actor sustainability-oriented innovations in the agri-food context

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Abstract
Sustainability oriented innovation (SOIs) are multi-faceted types of innovation which can address the challenges of the agri-food industry, tapping knowledge into a diverse set of stakeholders with their areas of expertise. There is currently a lack of conceptualization of all the relevant aspects to discriminate among different SOIs, also in terms of type of stakeholders involved and their roles in the innovation development process. We propose a conceptual framework based on three levels of analysis: *process, value network and maturity of the innovation system* to guide the characterization of SOIs. We obtain confirmatory evidence from 11 pilot projects in Europe.

Keywords: Sustainability-oriented Innovations, Agri-food, Multi-actor

Introduction
Sustainability oriented innovations (SOIs) integrate environmental and social aspects into products, processes, and organisational structures. There are different paths to establish SOIs, which depend on goals and areas of focus as well as on the innovation ecosystem within which SOIs are developed (Adams et al., 2016). The agri-food context is exposed to several grand sustainability challenges (e.g., climate change, assuring food security for all, and supporting the sustainable growth of small-scale food producers). Such challenges are also called *wicked problems* and they cannot be addressed by single organizations alone, as they require supply chain-wide and collective actions to tackle their implicit uncertainty and to tap into new capabilities (Hautamäki and Oksanen, 2016). hence, this creates opportunities for SOIs based on multi-actor collaborations, including vertical collaboration (e.g., with customers and suppliers), horizontal collaborations (e.g., with partners from other industries and/or similar partners) (Dania et al., 2016) as well as cross-sectoral collaborations (e.g., with third sector organizations) (Cantele et al., 2020). Despite the potentials for collaborative actions by multiple stakeholders, wicked

problems are mostly managed separately by the different actors of the agri-food supply chain. Such an approach might turn out to be ineffective, for two main reasons: i) a single company generally develops solutions that are less effective compared to the ones developed by the whole supply chain; ii) a single company might not have the required skills and knowledge to develop more radical solutions. These factors can represent the main hurdles in developing SOIs to scale. Moreover, despite literature provides knowledge about recurring patterns in the innovation process (e.g., Bocken et al., 2014), to overcome these barriers, a holistic framework which classifies SOIs and support practitioners for the actual implementation in a multi-actor environment, is currently missing.

In this scenario, companies might struggle to have clear guidelines for the implementation of SOIs. These gaps stress the need for a systematic classification of the main features of otherwise very diverse and complex SOIs. Hence, we formulate the following research question: (RQ1) What are relevant variables to classify sustainability-oriented innovations in a multi-actor collaborative environment?

To answer this RQ, we develop a conceptual framework and a *typology* research design (Jaakkola, 2020), combining a deductive analysis of the main factors determining different type of SOIs, with an empirical validation through the application of these categorization to a set of 11 pilot projects that aim at developing SOIs in the agri-food industry.

The paper is organized as follows: in the first section we introduce the theoretical background, followed by an explanation of the methodology and the presentation of the conceptual framework. The last part of the paper is devoted to the description of the findings, which are discussed also in terms of practical and theoretical implications.

Theoretical background

Wicked problems in the agri-food context

Wicked problems are complex societal issues that cannot be tackled by a single organization (Hautamäki and Oksanen, 2016). They require extensive cooperation and many actors, even not conventional ones (Hautamäki and Oksanen, 2016), to contribute to a systemic change through multi-stakeholder partnerships (Dentoni et al., 2018).

Agri-food systems face many wicked problems, which threaten their sustainability, such as: depletion of natural resources in face of a growing population, climate change (Hautamäki and Oksanen, 2016), food waste in a world that is food insecure (Matzembacher et al., 2021), as well as an increasing power imbalance in the agri-food supply chain (Velázquez and Buffaria, 2017). These important wicked problems pave the way for finding innovative solutions, which can potentially lead to the establishment of radical type of sustainable innovation (Hautamäki and Oksanen, 2016).

Sustainability oriented innovations

The idea of sustainability-oriented innovations (SOIs) stands on the integration of environmental and social aspects into products, processes, and organisational structures (Klewitz and Hansen, 2014). SOIs involve purposeful changes to different practices within an organisation and across different organisations, which lead to the creation of environmental and social value, in addition to the economic one (Adams et al., 2016).

The literature on sustainable innovation and on sustainable entrepreneurship has provided different characterisation of SOIs. Adams et al. (2016) leverages two main concepts: dimensions (i.e., technical and/or people-centred) and approaches (i.e., operational optimization, organisational transformation, and system buildings). The approaches reflect different extent of improvement in the three sustainability dimensions, distinguishing incremental and radical transformation to product, processes, but also to an organisation and an entire system composed by multiple stakeholders. Moreover, for each approach, internal (in the case of operational transformation) and external linkages are created to leverage new forms of knowledge. Another characterisation is represented by Bocken et al. (2014), which in their classification of sustainable business model archetypes distinguish between: technological, social and organisational. Similarly, Klewitz and Hansen (2014) based their classification for SOIs on the different focus on different subjects for innovation: product, process and organisation. Finally, in the sustainable entrepreneurship literature, Schaltegger and Wagner (2011) distinguish different core motivation behind SOI, as the i) contributing to solve environmental issues creating economic value, ii) solving societal problems creating value for society or iii) contributing to change societal and market institutions (Schaltegger and Wagner, 2011).

As a whole, notwithstanding the multi-faceted nature of SOIs and the plurality of actors they involve, in literature they are currently distinguished mostly on the basis of the nature of the innovation/dominant innovation component

Multi stakeholder partnerships for SOIs

SOIs tend to solve complex and multi-dimensional challenges and, therefore, are developed leveraging linkages with diverse stakeholders (Adams et al., 2016) to tap knowledge from diverse sources and capabilities (Collins and Saliba, 2019). More radical types of innovation are linked with system-building SOIs, which aim at *doing new things with others* and which imply complex interactions with multiple not-proximate stakeholders (Adams et al., 2016). This is a paramount change in approach compared to two streams that are usually associated with sustainable development, which either see the stakeholders as the main source of pressure for a company to implement a sustainability strategy (e.g., Li et al., 2017), or multi-stakeholder partnership (de Bakker et al., 2019).

Multi-stakeholder partnerships have already been associated with industry-wide or cross-industrial initiatives to address wicked problems (e.g., Matzembacher et al. (2021) on food waste; Elia et al. (2020) on climate change). De Bakker et al. (2019) distinguish two types of multi-stakeholder initiatives: certification-based, for the definition of standards and verification mechanisms (e.g., multi-stakeholder movements for FSC, MSC, Fairtrade etc) and principles-based, which include a collective definition and institutionalization of framework to guide companies in sustainability initiatives (e.g., UN Global Compact, GRI, etc)

The focus proposed by stakeholder theory sees stakeholders' pressures as the main trigger of the sustainable innovation process, but it lacks the inclusion of stakeholders in the value creation effort. Multi-stakeholder partnerships instead aim at creating standards and/or institutionalize standards, but the different features of multi-stakeholder partnerships to develop SOI is under-studied.

Methodology

We develop a typology research design, which is a possible approach for conceptual paper and aims at creating new knowledge by categorizing variants of concepts in the form of organized knowledge (i.e., distinct types) (Jaakkola, 2020). We adopted a deductive approach starting from reviewing the literature on: SOIs (e.g., Adams et al., 2016; Klewitz and Hansen, 2014), collaborations on product and process innovation (e.g., Spina et al., 2020); multi-stakeholder partnerships (e.g., Dentoni et al., 2018), innovation maturity (Geibler et al., 2016).

After this theoretical elaboration, we performed inductive discrimination of the different features that characterize SOIs by collecting primary information from semi-structured interviews to 11 Sustainable Innovation Pilot (SIP) projects. Table 1 reports summary information regarding the pilot projects and the SOIs they develop. These pilot projects, developed in the context of the EU funded project PLOUTOS, enable an experimentation of multi-actor and complex SOIs. Each SIP represents an innovative combination of: i) behaviour changes, ii) collaborative business model innovation; and iii) data driven technologies, which target and engage farmers. Semi-structured interviews were performed jointly with all the different actors contributing to the implementation of the sustainable innovation pilots. In this way, we empirically validate our conceptualization of key variables to identify typologies of SOIs in the agri-food context.

Project code	**Country**	**Description**
SIP 1	Greece	Supporting a frozen fruit value chain with small farmers, to optimize production, reduce environmental footprint and re-use data for certification and subsidies
SIP 2	Italy	Better food-chain contracts for improved durum wheat production
SIP 3	France, Greece	Empowering customers through crowdsourcing to take back control over their food and create healthy, sustainable, fair-trade products
SIP 4	Spain	Traceability solutions covering the horticulture greenhouses value chain to improve operations, sustainability performance and brand recognition
SIP 5	Ireland	Smart farming on rural farms demonstrating its benefits in the wider agri-food community and co-creating new food products and services
SIP 6	Slovenia	Applying soil passport approach rewarding land owners/users and a precision farming solution to increase soil health and sustainability
SIP 7	Cyprus	Supporting wine producers to take advantage of the changes in labelling regulations and enhancing their sustainability performance
SIP 8	The Netherlands	Carbon farming: compensating farmers for climate friendly soil management
SIP 9	Serbia, North Macedonia	Facilitating the transfer of surplus food from farmers to socially disadvantaged groups, by aligning logistics and processes
SIP 10	Italy	Increase sustainability in the grapevine sector by introducing payments for ecosystem services provision and parametric insurance to support losses from sustainable approaches
SIP 11	Spain	Improving the sustainability of Balearic agri-food chains with Smart Farming and by using the collected info to organize agri-food tourism

Table 1 – Sample of pilot cases developing SOIs in agri-food

Conceptual framework

To understand the relevant variables to characterize SOIs in a multi-actor environment, we propose a conceptual framework (in Figure 1) based on three levels of analysis.

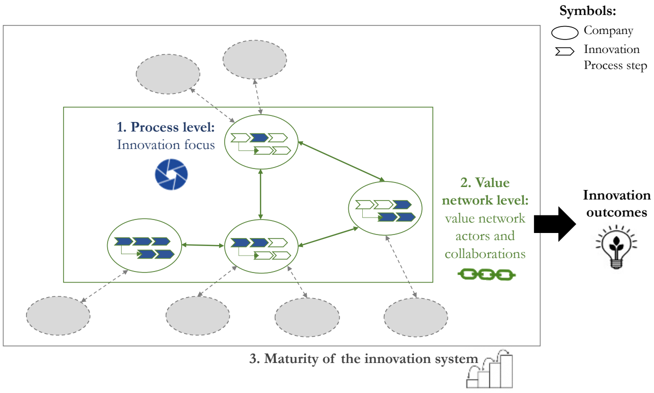
The first level is represented by the innovation focus. We claim that depending on a prevailing technological, organizational or social focus, the process steps in the development of SOIs can differ. The 3 types of innovation focus refer to the dominant innovation components proposed by Bocken et al. (2014), but with integrations from the works of Klewitz and Hansen (2014) and Adams et al. (2016). The technological focus includes SOIs that have a dominant technical innovation component (Bocken et al., 2014; Adams et al., 2016), thus focusing on the development of new technologies, or innovative application/extension of existing technologies in specific supply chains or for specific environmental compartments (e.g., soil health, GHGs emissions). The organizational focus relates to internal organizational changes (e.g., changes in the governance structure towards hybrid form) (Bocken et al., 2014) or changes in the supply chain (e.g., new geographic organization of the supply chain) (Klewitz and Hansen, 2014). Finally, the social component as presented by Bocken et al. (2014), has been extended beyond the development of new socio-cultural patterns for food consumption, considering also inclusive value creation (e.g., for the base of the pyramid) (Ritala et al., 2018) and of fairer distribution of the socio-economic value along the value chain (Dentoni et al., 2018), especially with the goal of enhancing farmers' condition.

The second level of analysis is represented by the value network. SOIs involve different types of actors which can activate different types of collaborations (Adams et al., 2016) with different goals and intensity. When a collaboration takes place with direct customers and suppliers (i.e., immediate stakeholders), authors refer to vertical collaborations (Dania et al., 2016; Sloane and O'Reilly, 2013), whereas when the collaboration is among competing organizations in the same supply chain stage, horizonal collaborations are developed (Dania et al., 2016; Sloane and O'Reilly, 2013). Finally, in the context of SOIs, diagonal collaborations play an important role. Diagonal collaborations involve non-traditional stakeholders, as public institutions, third sector organizations, and universities (Marques, 2019). Given the focus on organizational and social aspects, SOIs might need the support of actors that bring in the system knowledge and resources from different domains (e.g., technology) or other related industries (e.g., tourism). Moreover, SOIs can leverage a set of the so called "atypical" resources, knowledge and assets brought by third sector organizations (e.g., not for profit organizations, food banks, other public authorities). As a further element of analysis for value network interactions, SOIs can imply that, even with the same supply chain actor, companies can collaborate with a higher level of intensity, ranging for example from a purely technical support to co-design (i.e., joint development with separated decisional processes) and co-creation (i.e., joint development in which the boundaries for the decision-making process are blurred). Moreover, cross-sectoral collaborations also present different forms of engagement. We distinguish between: low engagement partnerships, with the aim of developing philanthropic initiatives (Shumate et al., 2018); and symbiosis, which has a more strategic intent for the development of social and inclusive innovations (Cantele et al., 2020).

The third level of analysis is represented by the *maturity of the innovation system*, which can be assessed through an evaluation of the maturity of the innovation projects in terms of scope and definition of roles and responsibilities for all the stakeholders who are most affecting or mostly affected by the innovations, thus enlarging the perspective from the sole value network actors.

Finally, we argue that the three levels of analysis impact the innovation outcomes. Table 1 summarizes the results of the deductive investigation of the literature with the criteria adopted for characterizing SOIs and the different typologies associated with each criteria.

Figure 1- Conceptual framework



Criteria	Typologies	Adapted from (main) reference
Main innovation focus	*Technological* • data driven technologies (DDTs) for sustainability • extension of existing DDTs *Organizational* • changing supply chain (SC) ties (e.g., contracts) • defining new SC ties (e.g., between tourism and agriculture) *Social* • redistributing value along the agri-food supply chain /power shift in society • create shared value for farmers	Bocken et al. (2014); Adams et al. (2016) Dentoni et al. (2018)
Value network actors	• Immediate stakeholders (e.g., customers and/or suppliers) • Potential/actual competitors or similar partners • External to the core supply chain/cross sectoral	Adams et al. (2016); Marques (2019)
Type of collaborations for the development of SOIs	• Technical support • Co-design/Co-creation (with third sector organizations:) • Low Engagement partnership • Symbiotic partnership	Spina et al. (2022); Cheng et al. (2020); Cantele et al. (2020)
Innovation system maturity	• Innovation system maturity (in terms of scope and definition of roles and responsibilities)	Geibler et al. (2019)

Table 2 – Criteria to characterize typologies of SOIs

Findings

Table 3 summarizes the application of the criteria to characterize SOIs on a set of 11 SIPs developed in different European countries. SIPs are classified according to the criteria explained in Table 2. The innovation focus reports the dominant innovation component of the SOIs, on which most of the innovation development process steps are focused. Nevertheless, for the nature of the SOIs developed by our sample of pilot projects, being inherently based on behavioural changes, collaborative business model and data driven technologies, all the three innovation targets are present in each SIP. Value network actors include immediate stakeholders (i.e., supply chain partners), which, for most of the SIPs, are farmers and processing companies, ii) similar partners (i.e., farmers part of an association); iii) partners that are external to the core supply chain, which in most of the SIPs are technology providers, but also research bodies and innovation hubs. Types of collaborations range from the simple technical support to co-creation and co-design. Finally, innovation system maturity provides a snapshot of the extent to which relevant actors are currently engaged with defined roles and responsibilities and with a defined scope. The maturity level is coded with a qualitative scale (*low, medium, high*) level.

Table 3- Characterisation of the different SIPs

Code	Innovation focus (*main*)	Value network actors			Type of collaborations for the development of SOIs		Innovation system maturity
SIP 1	***Technological:*** connecting smart-farming with a traceability solution for certification and to create better contract (organizational), which are more affordable (social)	*Immediate stakeholders:* farmers and frozen fruit processing company.	*Similar partners:* farmers members of a farmers' association.	*External to the core supply chain:* digital innovation hub, tech. provider.	*Technical support* with technology provider	*Co-design* with digital innovation hub	*Innovation system maturity:* high, all key stakeholders are already involved with clear roles and responsibilities.
SIP 2	***Organisational:*** changes in the contracts between farmers and the processing industry including parametric insurance added to an existing DSS (technological) for protecting farmers (social).	*Immediate stakeholders:* farmers; pasta processing company	*Similar partners:* farmers members of a farmers' association.	*External to the core supply chain:* Tech. provider and research institution	*Technical support* from the technology provider	*Co-design* with the research institution	*Innovation system maturity:* medium as the roles of the main stakeholders are clear and well defined, but the involvement and participation of insurance companies is not yet clarified.
SIP 3	***Social:*** ensuring a fair value distribution along the SC thanks to the direct involvement of consumers (organizational) in product design through crowdsourcing (technological).	*Immediate stakeholders:* consumers; farmers' representatives	*Similar partners:* farmers representatives from different countries	*External to the core supply chain:* Tech. provider	*Technical support* from the technology provider	*Co-creation* with customers	*Innovation system maturity:* medium-high, as key stakeholders are already involved with clear roles, but some farmers still need to be engaged.
SIP 4	***Technological:*** sensors in greenhouses to connect different sources of data along the supply chain (organizational) and communicating data regarding the local origin of the product (social).	*Immediate stakeholders:* farmers and processing company.	*Similar partners:* farmers members of a farmers' association.	*External to the core supply chain:* tech. provider.	*Technical support* from the technology provider	*Co-design* with the technology provider	*Innovation system maturity:* high, all key stakeholders are already involved with clear roles and responsibilities.
SIP 5	***Organizational:*** promote new agri-tourism services by introducing data-driven DSS (technological) to create stronger social network in the rural areas (social)	*Immediate stakeholder:* farmers	*Similar partners:* farmers association	*External to the core supply chain:* community coordinator, tech. provider, national farming research body	*Technical support* with technology provider	*Co-design* with community coordinator and national farming research body	*Innovation system maturity:* medium-high, all key stakeholders are involved but other actors could be actively involved as well (e.g. the tourist alliance)
SIP 6	***Organizational:*** applying a soil-passport approach to reward farmers (social) for increase soil health with precision farming technologies (technological)	*Immediate stakeholders:* farmers	*Similar partners:* not applicable	*External to the core supply chain:* digital innovation hub, public advisory service provider, tech. provider	*Technical support* with digital innovation hub	*Co-design* with digital innovation hub	*Innovation system maturity:* medium-high, all key stakeholders are involved but farmers are not fully engaged yet

SIP 7	***Technological:*** data-driven solution to connect smart-farming and processors with a traceability system to propose new business models (organizational) and affordability for farmers (social).	*Immediate stakeholders:* winery and exporting company	*Similar partners:* not applicable	*External to the core supply chain:* tech. provider, agronomic and scientific advisory services, agricultural research institute	*Technical support* with technology provider	*Co-design* with the agricultural research institute	*Innovation system maturity:* high, all key stakeholders are already involved with clear roles and responsibilities
SIP 8	***Technological:*** system to calculate sequestered carbon based on measures with a redistribution of value (organizational) to farmers (social).	*Immediate stakeholders:* farmers and organic retail chain	*Similar partners:* farmers' association	*External to the core supply chain:* academic partner and techn. provider	*Technical support* with technology provider	*Co-design* with the academic partner	*Innovation system maturity:* high, all key stakeholders are already involved with clear roles and responsibilities
SIP 9	***Social:*** platform ecosystem for the reduction of food wastematching supply and demand of surplus food (organizational) and by means of a digital platform to collect data (technological).	*Immediate stakeholders:* Farmers and other food waste producers and food waste redistributors	*Similar partners:* not applicable	*External to the core supply chain:* Impact Venture Studio orchestrating the system and developing the platform	*Technical support* from the Impact Venture Studio	*Co-design* with the Impact Venture Studio	*Innovation system maturity:* Medium-high, many key stakeholders are already involved with clear roles, but more actors could be involved in the ecosystem.
SIP 10	***Organisational:*** promoting sustainable and financially protected farming practices (social) through the DSS (technological) payments for ecosystem services provision and parametric insurance	*Immediate stakeholders:* Farmers	*Similar partners:* Famers members of the farmers' cooperative	*External to the core supply chain:* Tech. provider and research institution	*Technical support* from the technology provider	*Co-design* with the research institution	*Innovation system maturity:* medium-, roles in the project are clearly defined and so are the linkages between supply chain actors, but not all key actors are already involved
SIP 11	***Organisational**:* data-driven technologies in the agri-food supply chain to connect with the tourism sector (organisational) and to increase farmers' skills (social)	*Immediate stakeholders:* Farmers and the processing company	*Similar partners:* Farmers members of the farmers' cooperative	*External to the core supply chain:* digital innovation hub, tech. provider and the chamber of commerce	*Technical support* from the technology provider	*Co-design* with the digital innovation hub and the chamber of commerce	*Innovation system maturity:* Medium-low, it is not clear how the link between the agri-food supply chain and the tourism industry will be established

Discussion and conclusion

For the pilots project, which are currently under development, the conceptual framework does not prescribe ideal settings. Nevertheless, the criteria used to describe SOIs at the different levels of analysis can provide an overview of all the aspects to consider which might hinder the achievement of expected innovation outcomes, including a scaled-up implementation of the innovations.

According to the *process level* of analysis (see Figure 1), we claim that the innovation outcomes are influenced by a dominant innovation component (one among technological, social and organizational dimension), but that an additional focus on at least one the other two dimensions is needed. SIP 8 offers interesting insights in this regard. The main innovation focus of SIP 8 is technological, being based mostly on the development of a system which calculates sequestered carbon based on measures rather than traditional lab analysis. This pilot project is currently under development and, in addition to the dominant technological aspect, there is another important aspect connected to the distribution of value among the value network actors. The pilot project indeed aims at providing compensation to farmers based on carbon sequestration. Nevertheless, the financial compensation to farmers does not offset in the short-term the investment that has to be made. This can lead to less clear benefits perceived by farmers.

According instead to the *value network level* of analysis, in the conceptual framework we highlight that SOIs should also be analysed according to the type of actors involved and the type of collaborations they established. The absence of horizontal collaborations for SIP 7 (see Table 3) can hinder the scale up of the innovation. This difficulty is exacerbated by the fact that there is one company that controls the whole production process (i.e., a winery which also owns the land). With the same level of analysis, in SIP 10, the implementation of a decision support system (DSS) with the integration of a parametric insurance for farmers, requires tapping into the expertise of different stakeholders, which all possess critical knowledge. While the technology provider and the farmers are part of the value network, the insurance company is not yet involved. This is causing a lack of insights on the perspective of a paramount actor, about for example a possible pricing strategy for the insurance or for the risk estimation.

Finally, according to the *maturity of the system level* of analysis, in the conceptual framework we argue that the extent to which all the relevant actors are involved and with clear roles and responsibility is another relevant aspect contributing to the innovation outcomes. In SIP 11, which aims at creating new sustainable ties between the agri-food supply chain and the tourism industry, different actors are involved in the project (i.e., farmers and farmers' cooperative, a processing company and the chamber of commerce, representing the tertiary sector). These actors are involved in the project but they don't have clear roles and responsibilities and hence their innovation system level maturity is assessed as *medium-low*. The project has very relevant and ambitious goals and this condition is just a first warning and indicates priority of actions for the further development of the project to achieve the expected innovation outcomes.

As a whole, the criteria used to characterize SOIs provide a picture, grounded in theory, of all the diverse aspects to consider when developing SOIs. We believe that these results allow managers to receive guidance in the transition towards a sustainable agricultural system. Also policy makers can benefit from our study, thanks to a set of criteria to define funding or rewarding schemes for companies.

From a theoretical point of view, our work contributes to a more complete understanding on different forms of SOIs. By doing that, our work contributes to two streams of research. First, we enrich existing characterization of SOIs (e.g., Adams et al., 2016; Bocken et al., 2014; Schaltegger and Wagner, 2011). Second, this research also deepens the role of multi-stakeholders with an active role in developing SOIs. Stakeholders indeed established multiple forms of collaborations and their timely engagement appears to be an element of maturity of the innovation with consequences of the innovation outcomes that are validated by our case studies. Moreover, some preliminary evidence pointed out that the innovation outcomes seem to depend on the coherent design of the different criteria identified in our framework.

Limitations of the study concerns its conceptual and descriptive nature. Thanks to some preliminary evidence, we derive the importance of developing a path for SOIs coherent with the criteria of the conceptual framework. Nevertheless, further researches are needed aiming for example at applying the conceptual framework to diverse settings by specifically and quantitatively study the impact of the different criteria to characterise SOIs on the innovation outcomes.

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