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Article

Standardization as a Catalyst for Open and Responsible Innovation

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Abstract: Standardization, based on scientific and technological development, provides solutions for optimal level of order in a wide range of industrial, societal and environmental fields. Analogically to the process of open innovation, the development of standards brings together the knowledge and experience of different stakeholders, resulting in solutions that are relevant and accessible to the general public. Similarly, the concept of responsible innovation requires a variety of stakeholders to be involved in innovation development to ensure that their present and future needs are met. Although the link between standardization and innovation is a widely explored issue, the interaction of standardization with the increasingly relevant concepts—open innovation and responsible innovation—remains a research gap, therefore the aim of the study is to identify the common characteristics of standardization and open and responsible innovation, as well as to analyze the interaction between these concepts. The research is based on a literature review on the concepts of standardization, standards development and open, responsible innovation, as well as a field analysis on the ongoing activities in standardization in relation to innovation. The similarities and interaction between standards development and the creation of open, responsible innovation is analyzed and as a result a model that combines the characteristics of standardization, open and responsible innovation and their interrelation is provided. The findings of the study demonstrate that both the standardization process itself and its outcomes can be compared to the processes of open and responsible innovation and can also be characterized as a contributor for creating the environment for the achievement of sustainable development and fostering open and responsible innovation.

Keywords: standardization; standards development; open innovation; responsible innovation; stakeholder involvement; standardization research

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1. Introduction

The rapid technological development of the Fourth Industrial Revolution has created the environment for innovation based on combinations of technologies, the formation of new business models and stronger involvement of various stakeholders in business processes [1]. These considerations, together with consequently increased market uncertainty, introduces the necessity of standardized concepts. Although standardization can be described as a set of activities that to some extent unifies products, processes and systems, it plays an increasingly significant role in scientific and technological progress and industrial development, and is also identified as a driver of innovation and development based on considerations of conformity, safety, quality and ensuring common good of society [2,3]. In 2010, Swann stated that there is only a rather limited number of publications and empirical research evidence on the interrelationship between innovation and standardization, however, the number of studies on this interrelationship has increased significantly in the last decade [4]. Studies have found that the correlation between standardization and innovation can be identified in both facilitating innovation and hindering it, however, more emphasis has been put on the former [5].

In 1934, Schumpeter defined innovation as "the commercialization of all new combinations based upon the application of new materials and components, the introduction of new processes, the opening of new markets, and/or the introduction of new organizational forms" [5] (p. 57). The systematization of relevant knowledge of stakeholders through standards development contributes to the fostering of innovation and the growth of economy as it results in the diffusion of technical innovation and best practice. The standards development activities on the international level reveal that standardization coincides with the global industrial development and complements the introduction of innovations on specific areas of the Industry 4.0 such as artificial intelligence, additive manufacturing, unmanned aircraft systems, etc. In standardization, timing and openness are therefore critical to support and not hinder innovation effectively [6,7].

Through the work of technical committees that consist of experts from different countries, the International Organization for Standardization (ISO) has developed a portfolio of international standards and guidance documents for the use of organizations to align their systems and processes in order to undertake innovation activities and initiatives. According to ISO, standards help to put systems and processes in an order that creates added value and contributes to the harnessing and maximizing of innovation [8]. It is increasingly important to consider the concepts of openness and responsibility in the innovation process as sustainable performance and openness to innovation are crucial requirements for continuous development [9]. Standards are developed through the cooperation of relevant stakeholders. Analogically, in the concept of responsible innovation it is important to ensure early stakeholder involvement to increase transparency as well as alignment with societal needs, however, various obstacles for successful engagement of a variety of stakeholders is often identified both in innovation creation and standardization [10]. Recent studies have found that public policies and the inbound and outbound practices typical to open innovation have a significant positive influence on the eco-innovative performance of companies. However, the benefits may differ from the scope of the companies considered [11].

Although the link between standardization and innovation and the impact of open and responsible innovation on the development capacity of companies can be considered as widely explored issues individually, the interaction of standardization with the increasingly relevant concepts—open innovation and responsible innovation—based on the analysis of current and previous studies remains a research gap.

The aim of the study is to identify the common characteristics of standardization and open and responsible innovation, as well as the interaction between these concepts. In this study, the common characteristics of standardization and the concepts of open and responsible innovation are analyzed and the role of standardization in fostering innovation, as well as the interrelation of these processes is identified to answer the proposed research questions:

- RQ1—what are the common characteristics of standardization and the concepts of open and responsible innovation?
- RQ2—what is the interrelation between standardization and the concepts of open and responsible innovation?

The section "Literature Streams and Concepts" covers literature analysis on the issues of standardization and standard development, the concept of open innovation and the concept of responsible innovation. As a result of the literature review, the main characteristics of the aspects are identified and their distribution by time periods is presented. The literature review results in a description of the interrelation between the aspects analyzed.

In the section "Results", the answers to the research questions RQ1 and RQ2 are provided through the identification of common characteristics of standardization and the concepts of open and responsible innovation and a model that characterizes the interrelation between standardization and the concepts of open and responsible innovation.

The sections "Discussion" and "Conclusions" identify the main results and considerations on the issues researched in the paper, the limitations of the research, as well as the opportunities for further research of the issues.

2. Materials and Methods

The methodology was based on a literature review of scientific publications from two databases—Scopus and Web of Science. The selection of literature sources began with the identification of relevant keywords—standardization, standards, open innovation, responsible innovation. In the databases, open access publications were searched using the identified keywords. A total of 84 publications that correspond to the keywords were selected through the review of their abstracts and, through more in-depth analysis based on their relevance to the research question, 38 publications were selected for further analysis. The sources selected for the literature review cover the period from 2000 to 2021.

The literature review revealed the characteristics, links, similarities and interrelation between the concepts of standardization, open innovation and responsible innovation. During the scoping review, the main characteristics of the issues researched were summarized in Tables 1–3, adding references to the publication years and the authors of the ideas.

In addition, a field analysis on the ongoing activities in standardization regarding innovation was performed focusing on the policies and technical activity in international and European standardization, as well as the views of the European Commission on how standards will facilitate new production systems in the context of EU innovation and competitiveness in 2025. A total of 7 publications of European and international standardization organizations, the European Commission and the World Trade Organization were selected for analysis based on their relevance to the research topic.

Based on the findings of the literature review, logical analysis was applied to create groups of common characteristics focusing on different aspects of standardization and the concepts of open and responsible innovation and a model that reveals how the process of standards development interrelates with open and responsible innovation was created.

3. Literature Streams and Concepts

3.1. Standardization and Standards Development

ISO and the International Electrotechnical Commission (IEC) define standardization as "the activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context" [5] (p. 56). Standardization activities are implemented on different levels regarding various fields of interest. They ensure coordination, common social norms, openness, teamwork and knowledge sharing between different stakeholders based on common policies, rules and principles for standards development [6,12]. In 2008, the European Commission characterized standardization as the voluntary development of technical specifications based on consensus amongst interested parties. These include the industry, public authorities, consumers and other relevant interest groups. The result of standardization is the publication of voluntary standards that are available to the public [6]. Standards setting can be described as a voluntary self-regulatory process as standardization documents are developed as the result of a transparent consensual negotiation among firms and other interested stakeholders, and are mostly the result of a market driven process [7,13]. The involvement in standards development introduces benefits for organizations as the lack of participation in standards setting means that the organization will have to 'play the game' where others have formulated the rules [3].

Along with the economic impacts, equally important are the qualitative impacts introduced in the standardization sectors such as the environment, health, accessibility, food and work safety that contribute to the concept of sustainable development. A well-functioning standardization system and strategy that considers these aspects can work as a catalyst for translating inventions, discoveries and new ideas into productivity-enhancing innovation [14]. Standards can be developed by companies, nongovernmental organizations, or consortia,

exist as informal (de facto) standards in the marketplace, or can be accepted on the wider level as de jure standards that are developed by standards development organizations [15].

On the organization level, product innovation in response to standards helps to create a competitive advantage [16]. Standards can bring significant influence to the success of innovation by creating a shared framework for innovation and establishing common rules. This also includes the definition of common terminology, setting the essential characteristics of a product, service or technology, and the detection of best practice within the ecosystems to ensure successful results [3,17]. According to the Organization for Economic Cooperation and Development (OECD), standards help to create a demand on innovations and can serve as tools for facilitating market entry of the diffusion of innovation in the case of market failure [7]. They can also be characterized as the lifeblood of innovation in the global knowledge economy as standards are required to enable knowledge and data transfer and to facilitate the interoperability of components within increasingly complex technology systems [14].

The recognition of the importance of standards in effective economic development can be emphasized due to the changes in global trade flows. A national standards system or infrastructure creates the foundation for the functioning of a national quality system and a national technology innovation system. Standardization is characterized as a catalyst for innovation on a national or company level through the facilitation of access to markets and enabling the interoperability among new and existing products, services, processes and technologies [18,19]. The development of standards is also connected to the establishment of patents and intellectual property rights (IPR). Studies on the company level have revealed that standardization with the interaction of IPR has an innovation enhancing effect, for example, on the investment in innovation and the selection, coordination and diffusion of technologies [20]. Standardization is one of the criteria applied to define a promising patent considering technological commercialization in the open innovation context and empirical evidence has indicated the interrelation between standards setting organizations and the successful selection of patent protected technologies, as well as the long-term success of these companies in relation to the received patent citations [21,22].

The characteristics of standardization and standards development are summarized in Table 1.

Table 1. The characteristics of standardization and standards development.

Year	Characteristics of Standardization and Standards Development	Author
2004, 2008 and 2015	Establishing provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context.	[5,17]
2004 and 2020	Enhancing innovation through the interaction with IPR through investments and the selection, coordination and diffusion of technologies.	[3,17,20]
2008, 2013, 2017 and 2019	Voluntary self-regulatory development of technical specifications based on consensual negotiation, coordination, common social norms, openness, teamwork and knowledge sharing between different participants.	[6,7,13]
2009, 2014 and 2019	Facilitates access to markets and enables the interoperability between new and existing products, services, processes and technologies.	[7,14,18,19]
2013	Applies uniform requirements, is focused on the development of the industry and business activities, raises the level of quality through focus on resource efficiency.	[2]
2020	The standards development process includes set stages and is based on common policies, rules and principles.	[12]

Through these characteristics standards play a key role in streamlining complex systems and technologies, addressing the needs of stakeholders and ensuring consideration of the changing market needs and scientific developments [23]. By accumulating the knowledge of different stakeholders, standards ensure the transfer of best practice, provide a common understanding of concepts, address the needs of industry, society, public authorities and nongovernmental organizations, and thus foster the processes of coopera-

tion between different stakeholders in creating innovation and promoting the removal of barriers for international trade.

3.2. The Concept of Open Innovation

Nowadays, the Fourth Industrial Revolution has created the environment for technologies to flow across the boundaries of organizations, thus the paths to technological commercialization have diversified introducing the era of open innovation and the emergence of new business models [1,21]. Open innovation processes are connected with the absorption of external knowledge to obtain innovation through differentiated resources, procedures and routines [24]. In 2003, Chesbrough defined open innovation as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation" [25]. The ecosystem for social open innovations provides scope for connecting corporations and communities [26,27].

The involvement of external entities not only as observers but primarily as participants in the process of innovation contributes to the opening of organization boundaries. Open innovation and knowledge-based decisions introduce benefits to help to increase the efficiency of organizations. In addition, it introduces the use of patent licensing to acquire the necessary technologies or commercialize the technologies of companies [21,28]. Open innovation culture can be considered a driving force for established and start-up business development. Open innovation and the integration of internal and external resources contribute to the improvement of competitiveness of companies and can foster corporate innovation and thus introduces opportunities for further growth and development. The external resources may not be limited to other companies but also government support, social organizations and individuals [27,29,30].

Consequently, the acceptance of the open innovation concept as a basis for innovation creation and business development has grown through the interaction with external entities [28,31]. Open innovation can take different shapes: between social markets and diverse technology, potential markets and diverse technology and diverse markets and protected technology, as well as diverse markets and secret technology. These different types of open innovation contribute to the achievement of different styles of business model innovation [32].

Table 2 summarizes the characteristics of the concept of open innovation.

Table 2. The characteristics of the concept of open innovation.

Year	Characteristics of the Concept of Open Innovation	Author
2003 and 2020	The use of purposive inflows and outflows of knowledge through differentiated resources, procedures and routines to accelerate internal innovation, and expand the markets for external use of innovation.	[24,25]
2004 and 2018	Contribution to the opening of organization boundaries through the involvement of external entities as participants in the process of innovation, thus ensuring the efficiency and effectiveness of the innovation process.	[28,31]
2017	If a scope for the connection of corporations and communities is provided, open innovation can be considered social.	[26,27]
2016 and 2020	Connecting social, potential and diverse markets with protected, secret and diverse technology through the involvement of different stakeholders.	[30,32]
2018 and 2020	Extending the flow of technologies outside the boundaries of organizations, introducing new business models, the diversification of paths to technological commercialization and the development of the eco-innovative performance of companies.	[1,11,21]
2020 and 2021	A driving force for established and start-up business development, a contributor for the improvement of competitiveness of companies that fosters corporate innovation and thus introduces opportunities for further growth and development.	[27,29]

In open innovation, companies do not limit their developments on internal knowledge or resources but source external knowledge, involving the sharing of information, capabilities and intellectual property with other organizations. The process of open innovation therefore ensures the connection of different markets and introduces opportunities for diversification of technological commercialization. These considerations indicate similarities with the processes of standardization as the development of standards combines the knowledge and experience of different stakeholders in order to achieve the preferred solution.

3.3. The Concept of Responsible Innovation

Over the past decade, focus has been set on inclusive innovation as a strategy for more inclusive and sustainable development. Responsible innovation is oriented on public engagement and can be characterized by the inseparability of technical and social considerations [33,34]. The scale of social and environmental problems lead to the necessity to demonstrate the commitment of organizations to sustainable development. On the organization level, responsibility and sustainability must be among the values of the organization in order to be able to define sustainable development [9,35]. Consequently, responsible innovation is becoming an increasingly important concept as it is focused on searching for solutions to challenges which can guarantee sustainable development that is achieved through integration and cooperation [34].

Responsible innovation (RI) has emerged as a concept close to responsible research and innovation (RRI), but is focused on the innovation process itself. With the aim of providing a governance framework for responsible innovation, Stilgoe et al. provided four dimensions of RRI processes in 2013: anticipation, reflexivity, inclusion and responsiveness. In 2017, proposals for the inclusion of new dimensions in the framework were made. These include sustainability and care [36,37]. Through responsible or social innovation, the relationships among corporations, communities and civil society organizations can be developed. This introduces the importance of mutual reciprocity, responsibility and also willingness to learn from each other, and to build the capacity of each participant [26]. Similarly to standardization, early stakeholder involvement is considered a crucial element to increase transparency and alignment with societal needs and democratic values in responsible innovation [10,38]. This type of cooperation also introduces the environment for the creation of enhanced innovations with lower implementation costs based on new forms of cooperation with different networks [34].

The considerations above are summarized in Table 3 and reflect the characteristics of the concept of responsible innovation.

Table 3. The characteristics of the concept of responsible innovation.

Year	Characteristics of the Concept of Responsible Innovation	Author
2013, 2017 and 2019	The dimensions of RRI, a concept close to RI, include anticipation, reflexivity, inclusion, responsiveness, sustainability and care.	[36,37]
2017	Development of relationships among corporations, communities and civil society organizations.	[26]
2019	Searching for solutions to challenges which can guarantee sustainable development, achieved through integration. An environment to create enhanced innovations with lower implementation costs based on new forms of cooperation with different networks.	[34]
2020	Early stakeholder involvement is crucial to increase transparency and alignment with societal needs and democratic values.	[10]
2021	Leading to more inclusive and sustainable development, providing for public engagement and ensuring the inseparability of technical and social considerations.	[33,34]

Responsible innovation implies the necessity to involve and identify the needs of stakeholders, as well as to focus on the ideas of sustainability, thus building cooperation and relationships among different groups of interested parties. Ensuring transparency is also an important feature of responsible innovation and is the case for standardization as well as ensures the opportunity for all interested parties to follow and contribute to the processes of innovation and standards development. The characteristics of responsible innovation thus introduce an environment for the creation of solutions that are based on public engagement and reaching sustainable development.

3.4. The Interrelation between Standardization, Open Innovation and Responsible Innovation

Although *standardization* and the concepts of open and responsible innovation can be characterized individually, the aspects summarized in Tables 1–3 indicate that similarities and even interactions between these concepts can be identified as standardization and its principles can contribute to the fostering of innovation.

Technological complexity and market uncertainty that converts technological input into new, innovative products is a process of high risk that requires extensive use of technology standards, therefore, innovation outcome is primarily motivated by the interrelation between standardization and technology lifecycles [39].

In 2009, Blind described the characteristics of standardization as a catalyst for innovation considering the following:

- The reduction of the time to market of inventions, research results and innovative technologies;
- The promotion of diffusion of innovative products;
- The levelling of the environment for innovation and therefore promoting competition and consequently innovation;
- The facilitation of the substitution of old technologies and allowing the coexistence of old and new technologies;
- The reflection of user needs and therefore promoting the purchase, i.e., the diffusion, of new products by early adopters [40].

An equally important aspect that also characterizes the catalytic functions of standardization on innovation on the organization level is that standards can systematize the business environment and ensure the coordination of processes in a highly structured way, thus facilitating the processes of innovation [2].

In 2004, Chesbrough defined the engagement in standardization as a form of outbound open innovation, where technical information is revealed but is also a source for inbound open innovation where companies learn from each other [7]. Gassman et al. characterize the process of open innovation by three archetypes—the outside-in process, the inside-out process and the coupled process which can also be compared to the process of standards development as it requires the collection of knowledge of interested parties, sharing the outcomes for wider use and coupling these processes to create new deliverables [31]. The role of standardization in promoting responsible innovation, in turn, can be characterized by the importance of taking into account the views of all stakeholders in the standards development processes, based on consensus principles, and analyzing the potential impacts on safety and the environment, thus including also the aspects of sustainability [7,41].

The results of the literature review thus reflect that the considered aspects share common characteristics and interact with each other, thus providing answers to the research questions raised at the beginning of the study.

4. Results

4.1. The Common Aspects of Standardization, Open Innovation and Responsible Innovation

Taking into consideration the specifics of the concepts analyzed above, similarities between the concepts of standardization and innovation can be found, thus answering to the RQ1. The key aspects that characterize the correlation between standardization, open innovation and responsible innovation are illustrated in Figure 1.

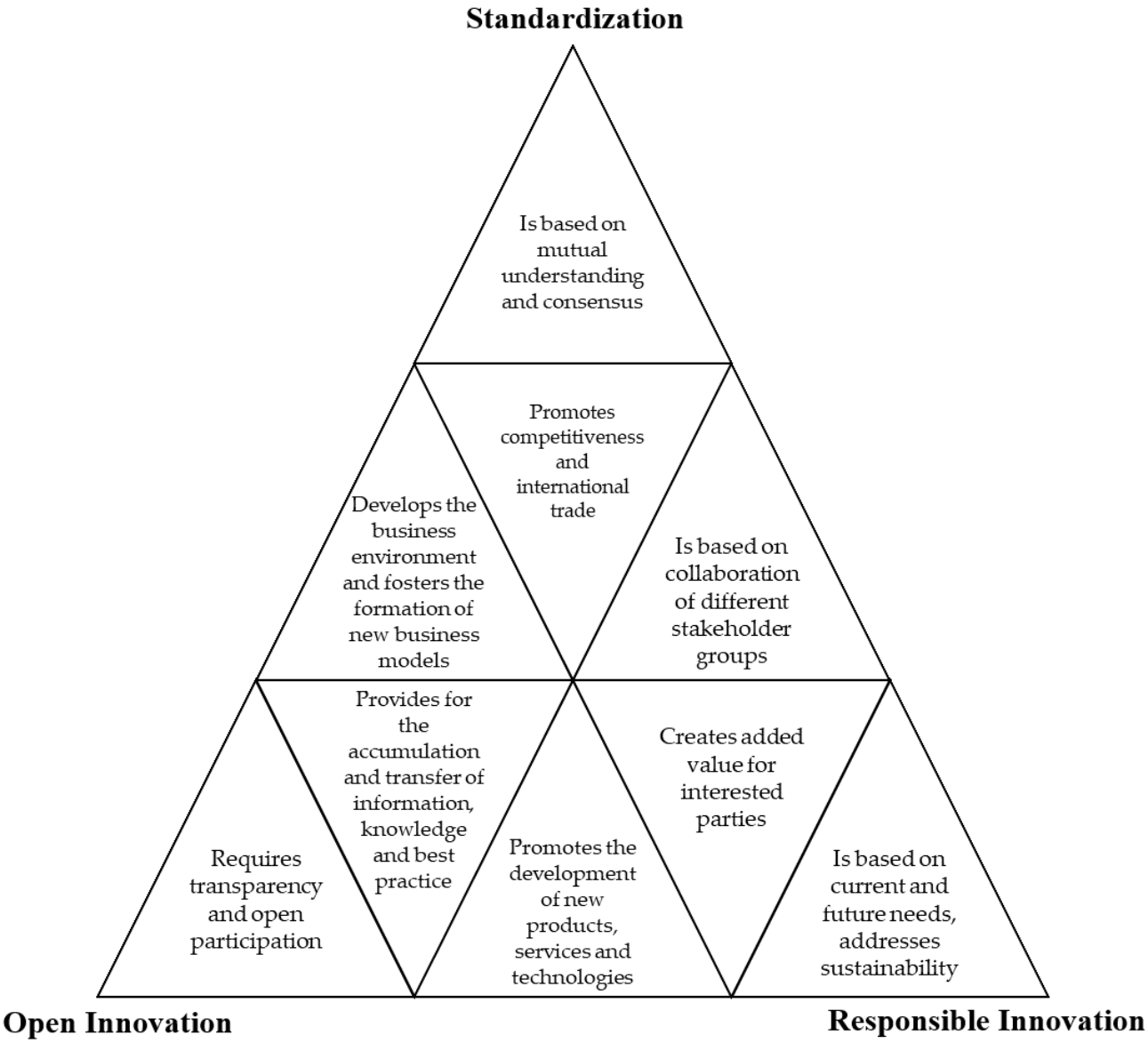

Figure 1. The common aspects of standardization, open innovation and responsible innovation (created by the authors).

As seen in Figure 1, the concepts analyzed above share common characteristics relating not only to the input of these processes, such as the involvement of different stakeholders and the accumulation of information, knowledge and best practice, but also to the results of these processes, such as the creation of added value for interested parties, promotion of competitiveness and international trade, the development of new products, services and technologies, and the formation of new business models. The common characteristics also reveal the considerations to be taken into account in the processes of innovation and standards development, such as the current and future needs of different stakeholder groups, the application of openness, transparency, and consensus in decision-making, and addressing the issues of sustainability.

Similarly to the concept of open innovation, standards are developed and implemented through open and transparent processes, they help to create opportunities for product differentiation and promote more choices for users [17]. Standards set the minimum requirements for environmental, health and safety aspects and consequently promote trust, especially in innovative products [40]. Moreover, by introducing the aspects of responsibility as in responsible innovation and the transparency and openness of standard-

ization processes by accumulating the knowledge of different stakeholder groups as in open innovation, the interconnection is enhanced.

4.2. The Interrelation between Standardization, Open Innovation and Responsible Innovation

The previous findings have already highlighted that standardization can act as a catalyst for innovation, therefore not only the common aspects, but also the interrelation between the concepts considered can be observed, thus providing an answer to RQ2. The considerations of the characteristics of standardization as a catalyst for innovation and the similarities between the processes of standardization and open, responsible innovation, together with the similarities that focus on addressing the needs of stakeholders, makes it possible to develop a model that reflects the interrelation and interaction of these concepts (see Figure 2).

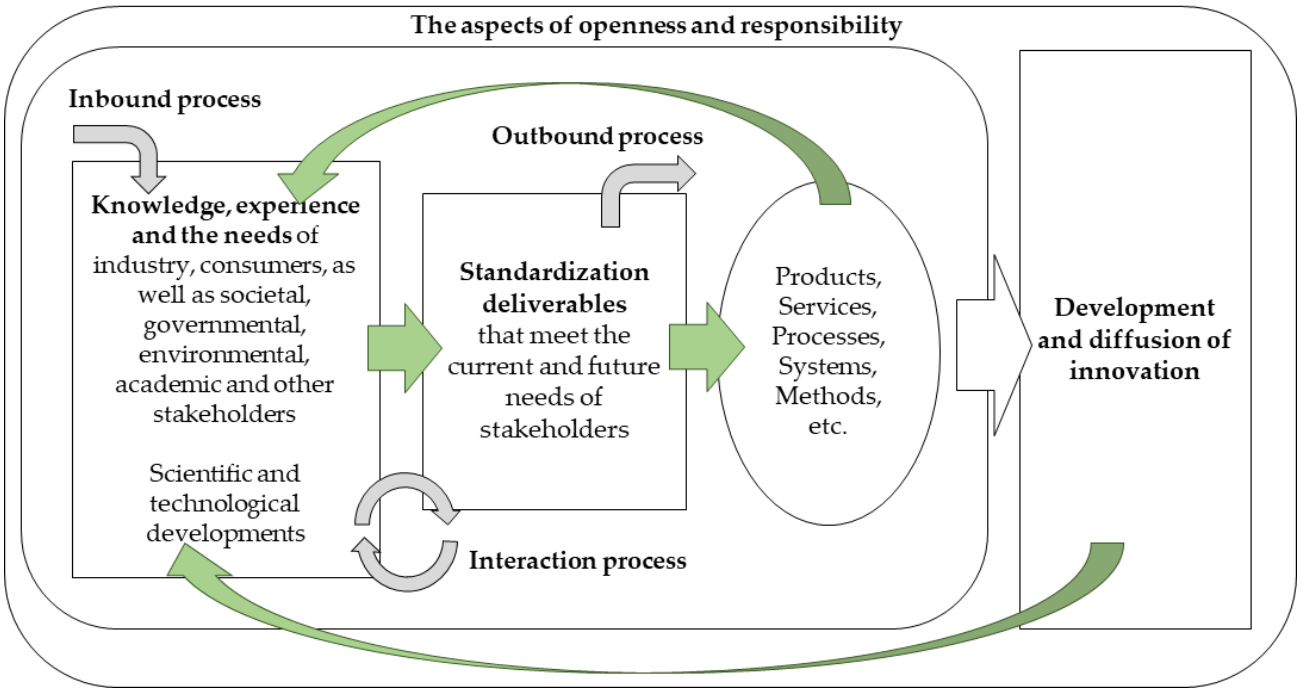

Figure 2. The interrelation between standardization and open and responsible innovation (created by the authors).

As mentioned before, principles applied in international standardization include openness, transparency and addressing the needs of different stakeholders, therefore, these considerations correlate with the concepts of open and responsible innovation. Considering standards development and based on the ideas of Chesbrough and Gassman et al., the process can be characterized by three steps—the inbound process, the outbound process and the interaction process [7,31].

- The inbound process: the integration of scientific and technological developments and external knowledge of experts representing different stakeholder groups from a range of organizations or countries; obtaining the views of the stakeholders to ensure common understanding and to address the needs of the interested parties.
- The outbound process: providing standards users with standardization deliverables that meet the current and future needs of relevant stakeholders, bringing the standards to the market and business environment.
- The interaction process: developing new standards on the basis of previous versions of the standards, introducing new participants in the standards development process based on the principles of openness and transparency, thus introducing the possibility for standards users to become standards developers, learning from previous

knowledge and adding new experience and developments in the preparation of new standardization deliverables.

Standards are then applied to the development and improvement of products, services, processes, systems, methods and other areas, thus ensuring conformity to generally accepted state of the art, industry-specific solutions.

The knowledge accumulated, the relationships and chains of cooperation established between the stakeholders, as well as the development of new products, services and systems contribute to the emergence of new innovations. Taking into consideration the principles applied in the development of standards and the order of the operating environment of organizations resulting from the application of standards, the possibility of creating innovations based on the principles of openness and responsibility is ensured. In turn, this new set of technological solutions, good practices and levels of development creates a demand for new standardized solutions, thus making the process cyclical and continuous. The process, therefore, contributes not only to the economic development but also to the welfare of society through the application of principles of responsibility, openness and transparency, as well as to the efforts to achieve sustainability. These considerations indicate that standardization and the concepts of open innovation and responsible innovation not only share common characteristics but also interact and promote each other.

5. Discussion

The continuous development of international trade, changing market needs and the growing demand for new solutions that meet current and future needs of society fosters the necessity for new, integrated and interoperable solutions that conform to the state-of-the-art level of technological development in different industries. Standardized solutions provide support in addressing these considerations by combining knowledge, best practice and creating a platform for the development of new products, services and technologies. Emerging technologies and innovations provide an opportunity to implement solutions to various problems, however, the introduction of technological solutions does not always benefit society if the needs of interested parties are not addressed.

In the past two years, international standardization activities have introduced the deliverables of the technical committee ISO/TC 279 "innovation management"—standardized vocabulary, guidance on innovation management system implementation and innovation management assessment, as well as tools and methods for innovation partnership and intellectual property management. Through these activities, standardization of innovation management contributes to the achievement of 14 of the 17 United Nations Sustainable Development Goals [41]. Such standards introduce practical solutions and can be considered useful for organizations intending to implement innovation processes as innovation management can promote more efficient use of resources by reducing the costs and efforts required to create successful innovations [42]. They can also help businesses to respond to change in order to maximize opportunities for growth and development effectively through the reduction of associated risks. According to ISO, through the application of standards, companies can demonstrate their ability to manage innovation activities in order to achieve their intended outcomes: increased revenues and profitability, improved sustainability and resilience, greater ability to attract partners, collaborators and funding, and enhanced customer satisfaction [8].

In European standardization, the mirror committee of ISO/TC 279 on the European level is CEN/TC 389 "innovation management". The standards developed on the international level are adopted on the European level of standardization along with a technical report on the guidance on innovation management assessment. Consequently, these standards have become national standards in all member countries of the European Committee on Standardization (CEN). On the European level, three technical specifications are also developed by CEN/TC 389. The specifications focus on different dimensions of innovation management: strategic intelligence management, innovation thinking and intellectual property management [43].

Addressing research and innovation in European Standardization activities and deliverables is also one of the priorities of CEN and the European Committee for Electrotechnical Standardization (CENELEC). The committees have developed the CEN-CENELEC Innovation Plan which includes an aim to strengthen the engagement with researchers and innovators in standardization processes. The actions of the plan envisage the development of agreements between national standards bodies and research organizations such as universities, research and transfer organizations or research departments to foster the collaboration between the CEN-CENELEC national members and the local research and innovation community. In order to facilitate the implementation of this plan, CEN-CENELEC Guide 23 is developed and contains a set of steps and recommendations for national standards bodies to achieve this cooperation through activities such as the exchange of employees, sharing of resources, agreeing on IPR and rules for publication [44]. The activities in standardization at the international and European level indicate that standards are not only tools for facilitating the implementation of innovation activities, but the standardization system as a whole acts as a platform for ensuring an appropriate environment and a channel for cooperation in innovation processes. In addition, given the basic rules that apply to standards development processes, the principles of openness and responsibility are applied in innovation creation through this interaction. Standardization activities on innovation bring benefits not only for the industry but also regulators and consumers. For regulators and policy makers, standards create a base on which to develop public policies that encourage innovation towards a more sustainable and resilient society. Consumers, however, benefit from new and improved products and services through the increase of innovation capabilities of companies [8].

The processes of open innovation, considerations of responsibility and new technologies and platforms are increasingly enabling different stakeholders to engage with governments, thus systems of public engagement and policymaking need to be adjusted to these processes [1]. A study by the Joint Research Centre of the European Commission identifies five priority areas of standardization in Europe: standards for integration, standards for environmental sustainability, standards for quality and performance, service standards and 'de-risking' standards. The foresight study is a first attempt to test the use of forward-looking techniques in standardization, it uses a holistic approach based upon the development of the Industrial Landscape Vision, 2025. The study also reveals the necessity of enhancements in European standardization system regarding new approaches to keep pace with technological development, ensure information accessibility, transferring science into standards and other issues that could contribute to the facilitation of innovation [45].

It can be concluded that the increasing considerations of safety, the environment, accessibility and other aspects make it necessary to obtain the views of the various stakeholders and seek for ways to bring solutions to current and future problems by not causing negative effects but adding value to the stakeholders involved. These conditions make the concepts of open and responsible innovation increasingly important in technological development, therefore, these issues are especially addressed in policy development, as well as in international standardization, however, the influence of these policy and strategic actions on the ability of organizations to increase their capability to create openness, responsibility and sustainability based innovations may be an object for future research agenda.

6. Conclusions

The study resulted in a literature review on the concepts of open, responsible innovation and standardization from which a set of aspects that characterize the links and similarities between these concepts was derived. In this study, the authors focused on formal standardization and the general standards development processes performed on the international level and the European level (i.e., the development of ISO, IEC, CEN and CENELEC standards). As a result, a set of characterizing factors that describe the common aspects of standardization, open innovation and responsible innovation was created and the answer to the research question—how standardization can foster open and

responsible innovation—was provided through the creation of a model which illustrates the correlation between standards development, the open innovation process archetypes and the consideration of responsibility aspects.

The literature review and field analysis conducted in this study revealed a number of links between standardization and the concepts of open and responsible innovation, thus providing an answer to RQ1: the study revealed that these concepts share similarities by characteristics such as the collaboration of different stakeholder groups, the ensuring of mutual understanding and consensus, and the application of principles of transparency and open participation through the accumulation and transfer of information, knowledge and best practice. The concepts also address current and future needs of society and other stakeholders, the ideas of sustainability and create value for interested parties. The findings also revealed that standardization, open innovation and responsible innovation contribute to the development of the business environment and foster the formation of new business models, thus also promoting development of new products, services and technologies and promoting competitiveness and international trade.

The aspects considered revealed not only the similarities between these concepts, but also the contribution of standardization to the development of innovation, as well as the effect of innovation to promoting the need for standardized solutions. The model developed as a result of the study confirms that the development of standards and the creation and diffusion of innovation are interconnected and cyclical processes that, taking into consideration the principles of openness and responsibility, can contribute to the development of economy, ensuring the consideration of the needs of different stakeholders, facilitating the reaching of common understanding of developing concepts, as well as ensuring progress towards achieving the goals of sustainability, thus providing an answer to RQ2.

The limitations of the study can be described through the extent of analysis that was based only on the literature review and the observations of the authors on the interrelationship of the concepts, as practical aspects, including business benefits, were identified only based on the publications and based on the analysis of strategic issues of policy development and technical activity within the international and European standardization system.

Limitations on the scope of the study were also introduced by the existing research gap regarding the issues analyzed. Although the processes studied in this paper are based on similar principles, the interrelation of the concepts has a potential for further investigation. For example, a research gap has been identified on the innovativeness of companies and their involvement in standardization as a specific form of open innovation strategy that can provide potential success factors in the receipt of procurement contracts [7]. In addition, based on the literature analysis of the aspects, the policy implications relating to these issues and the identification of barriers for stakeholder engagement in the processes of standards development and open, responsible innovation can be further explored in a practical environment, focusing on specific stakeholder groups or areas of standardization.

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