U.PORTO

FEP FACULDADE DE ECONOMIA
UNIVERSIDADE DO PORTO

User Communities: from Nice-to-have to Must-have

Inês de Araújo Macedo Amorim

Dissertation

Master in Economics and Management of Innovation

Supervised by

Joana Costa

Luís Carvalho

2022

Acknowledgments

First, I would like to express my deepest thanks to Prof. Joana Costa, for all the support, guidance and knowledge shared over the last year. It was a complete honour to be able to work with her, and I will forever be grateful for her patience, advice, and availability throughout this journey.

Second, I would like to acknowledge the invaluable support from my family, my boyfriend, and close friends. Their support was crucial, always motivating and encouraging me to do my best, even during the less positive moments. Without them, this would never have been possible.

And lastly, I would like to thank all my colleagues and teachers for the great past 2 years. I will always remember this experience very fondly.

Abstract

With Industry 5.0 already on the horizon, firms need to adapt their strategies to better cater to an increasingly demanding and sustainability-conscious customer base. At the same time, the role of customers has shifted from a mere passive buyer to an active user, that not only demands products and services personalised to their needs and preferences but actively communicates them to other users and stakeholders, revealing the emergence of the Quadruple Helix model, namely the fourth helix. The users can be particularly interesting for firms when organized in user communities (frequently, through virtual spaces), as they aggregate valuable knowledge that is habitually scattered among them. To assess the role of user communities in fostering firms' innovation, we chose a quantitative approach where several econometric estimations were put in place. The empirical analyses reinforced the relevance of user communities across all innovation types (with increased relevance for product and process innovation). The robustness analysis further confirmed the results obtained. Policy recommendations and future research suggestions were drawn, further reinforcing the importance of considering the insights from these agents as vehicles of responsible innovations which will constraint the innovation paths towards a more eco-friendly production.

JEL Codes: O36, O31, M14.
Keywords: User communities, Open Innovation, Industry 5.0, Quadruple Helix model, CIS, logit models

Resumo

Com a aproximação da Indústria 5.0, as empresas precisam de adaptar as suas estratégias para melhor servir clientes cada vez mais exigentes e conscientes da relevância da sustentabilidade. Ao mesmo tempo, o papel destes clientes passou de mero comprador passivo para um utilizador ativo, que não só exige produtos e serviços personalizados às suas necessidades e preferências, mas também as comunica ativamente a outros utilizadores e intervenientes, revelando o surgimento do modelo *Quadruple Helix*, nomeadamente da quarta hélice. Os utilizadores podem ser particularmente interessantes para as empresas quando organizados em comunidades de utilizadores, uma vez que agregam conhecimento valioso (frequentemente, em espaços virtuais) que habitualmente se encontra disperso entre eles. Para avaliar o papel das comunidades de utilizadores na promoção de inovação nas empresas, escolhemos uma abordagem quantitativa onde várias estimativas econométricas foram implementadas. As análises empíricas reforçam a relevância das comunidades de utilizadores em todos os tipos de inovação (com uma acrescida relevância para a inovação de produto e processo). A análise de robustez reforçou os resultados obtidos. Foram ainda elaboradas recomendações políticas e sugestões de investigação futura, reforçando a importância de considerar o conhecimento destes agentes como veículos de inovações responsáveis que irão impactar o percurso da inovação no sentido de uma produção mais ecológica.

Códigos JEL: O36, O31, M14.

Palavras-chave: Comunidades de utilizadores, Inovação Aberta, Indústria 5.0, Modelo Quadruple Helix, CIS, modelos logit

A similar version of this document was submitted to the Sustainability Journal, under the manuscript ID: sustainability-1820428.

Index of contents

Index of figures

Index of tables

1. Introduction

Over the last 20 years, Open Innovation is an increasingly explored topic, discussed by academics and attracting the attention of innovation managers, practitioners, and policymakers (Bigliardi et al., 2020). In the second wave of the conceptual proposal, Chesbrough and Bogers (2014, p. 12) defined Open Innovation as "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model". This definition takes the innovation processes beyond the limits of an organisation incorporating external players, firstly inside the value chain and more recently heterodox agents such as customers and users (Venesz et al., 2022).

The "increasingly demanding and rapidly changing customer needs" withstand the also increasing need for firms to listen to and capture the customers' preferences and necessities (Mohamed, 2018, p. 257). As such, firms implement Open Innovation processes as well as other strategies to better capture diverse external knowledge, making them more agile, flexible, and efficient for their target markets (Carayannis & Campbell, 2009; Cepeda & Arias-Pérez, 2019). The reliance upon the external community is further leveraged by the expansion of information and communications technology (enabling easy, fast, and efficient communication between, virtually, anyone) and the increasing openness of enterprises, by sharing their challenges with external parties (Bogers et al., 2018).

In what relates to the ecosystem, alternative frameworks were being layered, successively encompassing additional agents with alternative roles in knowledge production and diffusion. As such, from the traditional Academic and Governmental players, users and the environment were called to leverage the innovative process speeding up its pace as well as its embedded responsibility. In this vein, the Quadruple Helix model emerges as a theoretical framework with four different stakeholders: government, academia, industry, and civil society (Carayannis & Campbell, 2012). This framework is in complete harmony with the concept of Open Innovation as the actions and decisions taken by each of these actors, are exposed to feedback from others, creating interaction and accountability.

An important set of recent academic studies (Shah & Nagle, 2019; Carayannis & Campbell, 2022; Venesz et al., 2022; Yun & Liu, 2019) focusing on the role of the "civil

society," analyse in detail the role of this player in the Open Innovation practices, with a big focus on the transition from "passive buyers" into active co-creators and co-developers of goods and services), but also as promotors of responsible developments in the innovation processes

However, there is a lack of empirical studies quantifying the role of the user communities in fostering innovation. Furthermore, there is a clear gap in the type of innovations these communities can impact (product process, marketing, or organizational innovations). With this in mind, the dissertation has the objective of understanding and quantifying the role of the user communities in fostering each innovation type, as well as the innovation intensity among Portuguese firms.

As such, the main research question of the dissertation is "What is the role of user communities in fostering the different types of innovations?" This evidence will allow a better understanding of how co-creation processes occur, the impact of user communities on a firm's innovation strategies, and, lastly, transpose these results into relevant information for firms who want to engage in these processes along with policy recommendations.

This user-centric approach is also compatible with the emerging paradigm of Industry 5.0. As we move from Industry 4.0 to 5.0, new challenges and necessities get the pride of place, such as sustainability, human-centricity, and resilience (Carayannis & Morawska-Jancelewicz, 2022; Xu et al., 2021). Firms that adapt their strategies taking into consideration these vectors (as opposed to only profitability), capture a competitive advantage by catering to and getting the trust of an ever-growing environmentally-conscious customer base (Wang, 2019; Nahavandi, 2019). But how can firms successfully implement sustainability-oriented strategies and still capture profits? As technologies evolve, the workforce will be released from repetitive tasks, and the role of humans in manufacturing will evolve to rely more heavily on critical thinking and creativity (Javaid & Haleem, 2020). Through the new paradigm of Industry 5.0, machines and human workers will work together, as machines will learn human intention and use it during their work (Nahavandi, 2019). This will be crucial for mass personalisation, as it will provide the tools to massively produce products tailored to the customers' requirements and specifications, namely, in the matter of sustainability (Javaid & Haleem, 2020). This

is crucial for firm strategies, as being sustainable is no longer an option but imperative (Xu et al., 2021). Increasingly demanding consumers are pushing the sustainability agenda and demanding transparency from firms, which will shape and deeply influence their decisions (Carayannis et al., 2021).

This implies a complete transformation of the Industry, transitioning into a circular economy by implementing processes and practices capable of not only using resources efficiently but also reducing the environmental impact of the products and services (Grabowska et al., 2022). It is already possible to observe significant changes being put into place by various types of stakeholders (Gur, 2020), such as public entities/government bodies – the European Commission has already implemented several strategies to promote Industry 5.0 (Xu et al., 2021); research institutes/universities – Industry 5.0 is a subject undergoing intense study by academics with over 230 publications [1] since 2016; consumers/users – contribute to this transformation through their demand of sustainability-conscious and personalised products/services (Carayannis & Morawska-Jancelewicz, 2022). Therefore, firms need to actively transform and adapt to this paradigm, to successfully keep up with this demand and maintain their competitiveness (Wasono et al., 2019). In addition, a holistic innovation policy perspective will be crucial for this transformation (Fagerberg, 2018; Gur, 2020).

The achievement of these purposes will rely very heavily on knowledge from the users, to adapt the firms' products and services according to their preferences and behaviours (Aquilani et al., 2020). The implementation of "data infusion, massive customized manufacturing processes and smart automation in the production process" which will incorporate said knowledge, will pave the way for Industry 5.0 (Maddikunta et al., 2022, p. 10). Furthermore, this also implies a significant transition in policy models, to a holistic approach that integrates the users, to successfully develop human-centred innovations (Carayannis et al., 2021).

"Users are increasingly acknowledged as important actors fostering those fundamental socio-technical innovations needed to achieve a sustainable society" (Meelen et al., 2019, p.1) given

[1] The search was conducted on Scopus on publications related to "Industry 5.0"

the characteristics of Industry 5.0 – as a human-centred paradigm focused on solving societal issues – the user communities are essential for the development of responsible innovations (Y. Wang et al., 2020). These innovations will have a crucial role in the successful shift toward a sustainable economy and environment. Sindhwani et al. (2022, p. 1) state that "the Industry 5.0 (I5.0) revolution is a call to bring forth the ideas of sustainability into practice, integrate human values with technology, and is considered a step forward for achieving sustainable development goals", as such, understanding the value of the engagement between user communities and firms is a requirement to effectively transition into the new emerging paradigm (Aquilani et al., 2020).

Despite the vast literature existing on co-creation and user communities, the quantification of the importance of these players in each innovation type is still overlooked, it is also lacking measure and quantification of the economic effects of user communities on firms, as pointed out by Shah and Nagle (2019). Most studies on the interaction of firms and users through co-creation processes focus exclusively on product innovation (meaning the introduction of new or improved goods or services to the market) (Markovic & Bagherzadeh, 2018), neglecting the other types of innovation, and the user community plays a determinant role not only making advancements in certain innovation but also deterring other paths of innovation and promoting alternative diffusion methods and continuous improvements. The insights from this community are also of extreme value in small incremental innovations as well as product improvements from original versions, updates, and re-styles.

With this gap in mind, the main goal of the dissertation will be to quantify the impact of user communities on the firms' innovation processes (measured through the engagement in co-creation processes with user communities). The impact measured will be in terms of innovation output (quantity and type – product, process, organisational or marketing innovations). The results obtained will shed light on the expected impacts on innovation related to the co-creation processes conducted by firms. These outcomes will provide valuable insights for firms, that can adjust their innovation strategy, namely, their interaction with user communities, according to the type of innovation they pursue. In this vein, the goal is to put into test the importance of the engagement with user communities in innovation outputs, providing valuable material to firms – who can use this evidence to better tailor their innovation strategy according to the expected outcomes –, as well as draw policy recommendations fostering the approach between these agents in the helix.

2. Literature review

In this chapter, relevant insights about the key concepts, Open Innovation, and user communities, will be explored and discussed. First, the concept of Open Innovation concept will be addressed, as well as the Quadruple Helix model, creating the theoretical foundations of the study. Then, several perspectives related to user communities will be addressed, such as their nature, motivations, relevance, and how they interact with firms. The aspects developed in this chapter are crucial to fully understand and explain the relevance of the engagement between firms and user communities.

2.1. Open Innovation

Open Innovation is a framework encompassing inwards and outwards flows of information circulating outside the organization boundaries of organisations (Chesbrough, 2003; Bogers et al., 2018). This framework emerged fostered by environmental factors such as the democratization of knowledge, significant development of Information and Communication Technologies, a greater degree of openness by large enterprises, and increasingly demanding consumers (Bogers et al., 2018; Mohamed, 2018).

At first, the definition of Open Innovation only concerned the relationships among actors of the value chains, however, the concept continuously evolved and broadened the scope of the firms' innovation processes, either by including additional actors – governments, research institutes/universities, other firms, consumers/users – or by being more geographically dispersed, making these processes evermore complex, holistic, and sophisticated (Etzkowitz, 1989; Chesbrough, 2003; Carayannis & Campbell, 2009; Vrande et al., 2010; Leydesdorff, 2011; Chesbrough & Bogers, 2014; West et al., 2014; Binz & Truffer, 2017; Yun & Liu, 2019; McGahan et al., 2020; Chesbrough, 2019).

As the problematic in debate focuses on the fourth helix of the framework, we will now focus specifically on the impact of the inclusion of user communities in innovation processes. The first paper referring to *user communities* in the innovation context[2] dates back to 2005 and examines the role of these communities as *innovation diffusers* of Open Source Software in

[2] The search was conducted on Scopus using the keywords "User community" and "Innovation"

firms, disrupting the software market led by Microsoft's Windows (Sieber et al., 2005). In this case study, the user community effects were indicated as the main reason for the adoption of this software in firms, revealing the influence capacity of these communities.

Moreover, one of the most relevant articles on this subject date back to 2006 and studies the attributes and motivations of users that actively contribute to firm-hosted user communities. It was conducted on the music industry and concluded that the users who actively engage in these communities are "hobbyists," lead users, and motivated by firm recognition (Jeppesen & Frederiksen, 2006). It was concluded that the benefits of relying upon these communities are dependent on the product and area of the organisation, indicating that areas more prone to hobbyists (such as consumer goods) are also more prone to benefit from the insights of these communities.

Recently, an article by Ek and Sörhammar (2022) was published they assessed the User Community Sensing (UCS) capability in the video game industry. The study found a positive correlation between product innovation and UCS, through the knowledge obtained by the communities (Ek & Sörhammar, 2022). However, no evidence was found regarding the increase in the speed of product development.

It is also worth mentioning, that these communities are relevant across all sectors (Shah & Nagle, 2019). The knowledge and information retrieved from them can be used by different industries (that would not be the obvious target audience), and to successfully transition into the Industry 5.0 paradigm, the transformation has to occur across the whole economy (Aquilani et al., 2020). The user community will allow speeding up the pace of innovation while preventing some hindering factors to the process (Costa & Matias, 2020).

Quadruple Helix model

The inclusion of additional actors in the innovation system is compatible with the Quadruple Helix model, in which "government, academia, industry, and civil society are seen as key actors promoting a democratic approach to innovation through which strategy development and decision-making are exposed to feedback from key stakeholders, resulting in socially accountable policies and practices" (Carayannis & Campbell, 2012, p. 1). Additionally, this model is characterized by both top-down government policies – similarly to the Triple helix model –, and bottom-up activities, capable of affecting

innovation, such as co-creation processes with the civil society (Etzkowitz, 1989; Yun & Liu, 2019).

As illustrated by the Quadruple Helix model, there are many sources of knowledge from different stakeholders – academia/universities, industry, government/public institutes, and society (Carayannis & Campbell, 2009; Carayannis et al., 2018). As innovation processes benefit from several types of knowledge and expertise, firms have a great incentive for fully engaging with all the stakeholders (Prause & Thurner, 2014; Cavallini et al., 2016). Focusing on the fourth helix, its relevance, and importance as a source of external knowledge is well recognized (Costa et al., 2021), however, its conceptualisations are not consensual among scholars (González-Martinez et al., 2021). Most of these conceptualizations of the fourth helix revolve around "citizens" (Carayannis & Campbell, 2012), "wider community" (Kolehmainen et al., 2015), or "users" (Roman et al., 2020; Compagnucci et al., 2021), for the following chapters we will employ the latter.

Quintuple Helix model

First mentioned by Carayannis and Campbell in 2010, the Quintuple Helix model introduces the *environment helix* to the previously mentioned Quadruple Helix (Carayannis & Campbell, 2009; 2012; 2014; Hasche et al., 2019). The fifth helix introduces the wider environment, including concerns with sustainability and ecology, thus, becoming a driver for eco-innovations and knowledge creation (Durán-Romero et al., 2020; Carayannis et al., 2017). In addition, the *environment helix* increases the complexity of the model as it entails a complete interdisciplinary and transdisciplinary understanding of the environment (Carayannis & Campbell, 2010; Carayannis et al., 2017).

As such, we consider the fifth helix to be of a higher level, in the sense that cannot be isolated from the others as it characterises its surrounding environment (Mineiro et al., 2021). Given this, it seems not to be possible to directly compare the environment with the other helices and even to accurately quantify or measure its impact on innovation. The environment is much closer to an embedding variable than a simple helix. Subsequently, for the present analysis and discussion, we shall disregard it and consider the Quadruple Helix model as the representation of the innovation ecosystem (Cai & Etzkowitz, 2020; Cai & Lattu, 2021).

2.2. User communities

"Users are the consumers of an enterprise's products who voluntarily participate in innovation tasks and submit solutions or ideas out of their interests or love of the products," (Liu et al., 2018, p. 6). User communities are groups made up of users with a common interest in an artefact (product or service), that work together (voluntarily), exchanging and developing knowledge that translate their own capabilities, preferences, recommendations, and needs (Shah & Nagle, 2020). These communities provide a common space (often virtual) for users with mutual interests to share their opinions, and experiences and interact with each other for the general purpose of knowledge development and exchange (Füller et al., 2006; Antorini & Muñiz, 2013). The communities are composed of various kinds of users, from amateurs to lead users and enthusiasts (Shah & Nagle, 2019; Schütz et al., 2019).

For the knowledge to be more significant, valuable, and accurate for firms, the user communities should have two characteristics:

- large dimension: the user communities need a large number of users to accurately represent the firm's target client (Oertzen et al., 2020). If the communities have a reduced number of users, the knowledge carried will not be as impactful, as it may not correctly translate the preferences, needs, or feedback of the larger pool of consumers (Surowiecki, 2004; Füller et al., 2006; Rayna & Striukova, 2015; Pan, 2020).
- diversity: to get the most out of the communities, the users should have different profiles (age, gender, education, user degree) to potentialize their creativity and to assure the presence of complementary skills, able to generate high-quality innovations and knowledge (Füller et al., 2006; Prause & Thurner, 2014; Rayna & Striukova, 2015; Schütz et al., 2019; Pan, 2020; Oertzen et al., 2020).

Why are these communities interesting for firms?

In general, firms can create a competitive advantage through two distinct strategies: low-cost or differentiation. The user communities can be beneficial for both strategies (Chatterji & Fabrizio, 2013; Antorini & Muñiz, 2013), however, as this work is focusing on the development of innovations, we will only focus on the differentiation strategy.

The user communities are a valuable source of knowledge for future innovations, as they can provide insights on features and improvements of their preference, which would then translate to commercial success (Etzkowitz, 2014; Prause & Thurner, 2014; Lee et al., 2022), either by providing feedback on existing products/services, by using them in unusual ways/contexts, not originally planned by the firms, or by introducing new or improved products created by the users themselves (user innovation) (von Hippel, 2017). Additionally, by involving the users in the innovation processes, firms can reduce costs and mitigate the risk of market rejection (Yang & Li, 2019). However, this knowledge is scattered and dispersed among all users (Hayek, 1945; Chen et al., 2020). To obtain correct and significant information, this knowledge has to be aggregated, which can be challenging given the substantial number of potential users. Concerning this, the development of ICT opened a world of possibilities, with the creation of online communities, which can be more easily managed by firms (Mahr & Lievens, 2012).

The notion of responsible innovation is not recent (Blok & Lemmens, 2015; Stilgoe et al., 2013; Hartley et al., 2019; Pansera & Owen, 2018), being extensively explored both on the subject of social technology studies and social corporate responsibility (Gallego-Álvarez et al., 2011). Business actions of a corporation actively contribute to answering societal challenges. Given that most innovation and research is conducted (and funded) by companies and industries, it is no surprise most innovation processes only focus on profitability, not factoring in possible negative impacts on the society and environment (Gurzawska, 2021).

However, both policy-makers and society are now more watchful of these practices (Gur, 2020), bringing both top-down (regulation and restricting funding opportunities) (Genus & Stirling, 2018; Voegtlin & Scherer, 2015) and bottom-up (demand) incentives for companies to pursue responsible innovation practices (Schlaile et al., 2017). To align these practices with the innovation outputs with the values of the society, which has to be included in the process by providing different inputs (social expectations, exchange of views, communicating needs and priorities) (Gurzawska, 2021). As such, the user communities are key stakeholders for responsible innovation (Compagnucci et al., 2021).

As previously mentioned, this notion is intimately related to the one of Corporate Social Responsibility (CSR) (Costa & Fonseca, 2022). CSR can be defined as the responsibility of

firms for their actions' impact on society. With this goal, the firms' processes should take into consideration their implications on various domains of the society - such as human rights and environmental issues -, and work in close collaboration with other stakeholders to better comprehend these impacts as well as put in place prevention or mitigation measures (European Commission, 2011). In order for firms and corporations to implement and strategize effective CSR practices, once more, it is a fulcrum to include the societies' needs and wants, namely, in terms of sustainability and environmental concerns, and the natural vehicle for this to happen is the user community.

But why is it beneficial for firms to implement and follow CSR practices? Even though these practices may result in added costs for firms (for instance, through getting sustainable suppliers or Fairtrade raw materials), these firms can gain the trust of the consumers, especially those more environmentally-conscious (Sprinkle & Maines, 2010; Księżak, 2017). On the other hand, focusing on profitability alone without considering sustainability can cost the loyalty of consumers in the long run (Mačaitytė & Virbašiūtė, 2018).

What is user-led innovation?

According to Eric von Hippel (2017, p. 1452), "user innovator is a single firm or individual that creates an innovation in order to use it". Several examples can be found in the literature, with the most prominent ones being related to medical devices and sporting goods (Grabher & Ibert, 2018). As such, these users create/develop/modify products or processes, capable of better fulfilling their needs than existing ones (or available to them) (von Hippel, 2005).

Eric von Hippel developed extensive literature on this subject, answering questions such as *Why do users want custom products?* or *Why do users share their innovations freely?* and developing the *Lead User Theory*. Focusing on the former, he argues that users' needs are very heterogeneous, and, because of this, mass-produced products will not be able to answer the needs of many users (von Hippel, 2005). As for producers, it is more efficient to produce a *one size fits all* product, as such, the users whose needs are not met by said product will be compelled to create/modify a fitting product themselves. But why do these users share their innovations freely, instead of profiting from them? It is extremely difficult for these users to successfully protect their innovations from imitation (Chesbrough et al., 2014; von Hippel, 2016). In this sense, the question for the users is

not *Should I protect my innovation?* but *Should I share my innovation voluntarily or should I wait for imitation to happen either way?* Given that, more often than not, the user innovators that share freely their innovations receive *private benefits* among communities - such as reputation, recognition, or social status (these benefits will be further developed in a later section), the users feel more compelled to share their innovations freely (von Hippel, 2005). Now focusing on the *Lead User Theory,* which theorises that most of the user innovations are developed by lead users (von Hippel, 2005). Lead users are characterised are at forefront of market trends, and highly interested in the product/service; given this, they are early adopters and test out the product/service before the majority of customers. These users also anticipate receiving significant benefits from getting a product able to answer their needs, leading to them innovating themselves, in order to get it (von Hippel 2005; Escobar et al., 2021).

General hypothesis: Firms' engagement with user communities increases innovation propensity in all innovation types

How do firms engage with user communities?

To successfully engage the user communities in the firm's innovation processes, these have to evolve from linear processes (that have the consumers as the endpoint) and truly integrate the users along the process, creating space for interaction and exchange of ideas and feedback from the users (Prause & Thurner, 2014; Roman & Fellnhofer, 2022). To do this, the firm's innovation processes need to be a cooperative process, where the communities actively participate in the production, development, design, and/or marketing of the products/services (Romero & Molina, 2011; Guo et al., 2017; Yun & Liu, 2019).

In this matter, the concept of co-creation emerges (Füller et al., 2009). Co-creation processes can be defined as activities and interactions in which the customers actively contribute to the design and development of new products or services involving the engagement of organisations (Ramaswamy and Oczan; 2014; Garcia et al., 2014; Romero & Molina, 2011). In these interactions, the customer is no longer a mere buyer, but a user able to provide valuable knowledge, which is, then, incorporated by firms and organisations in their innovation processes (Ramaswamy & Oczan, 2014; Grabher & Ibert, 2018; Yun & Liu, 2019; Roman & Fellnhofer, 2022). As a reward, the users get the co-developed products/services,

that have a greater value for them, as they were developed with their needs in mind (Romero & Molina, 2011).

In this context, both users and firms are simultaneously the key co-creation actors and beneficiaries (Liu et al., 2018). Figure 1 it is displayed the distinction between the *non-co-creative innovation process* and the *co-creative innovation process.* In the *non-co-creative innovation process*, the users and customers assume the role of validators, by providing feedback and opinions on the finalised product/service; assuming a passive role, outside the organization borders of the firm (Grabher & Ibert, 2018; Roman & Fellnhofer, 2022). This process does not involve the user or costumer directly in the product/service development, nor does consider their needs and ideas, as the communication between the firm and the customer only happens at the last stage of the product/service development (Durugbo & Pawar, 2014). Alternatively, in the *co-creative innovation process,* the users and customers are actively involved in the whole innovation process, exchanging knowledge and inputs throughout the whole journey (Zhang et al., 2020). The product/service is jointly developed, in a process that occurs beyond the organisational limits of the firm. Co-creation processes emerge as a way of implementing Open Innovation strategies, through the distribution of the innovation process through different actors (Roman & Nyberg, 2017; Abbate et al., 2019; Roman & Fellnhofer, 2022).

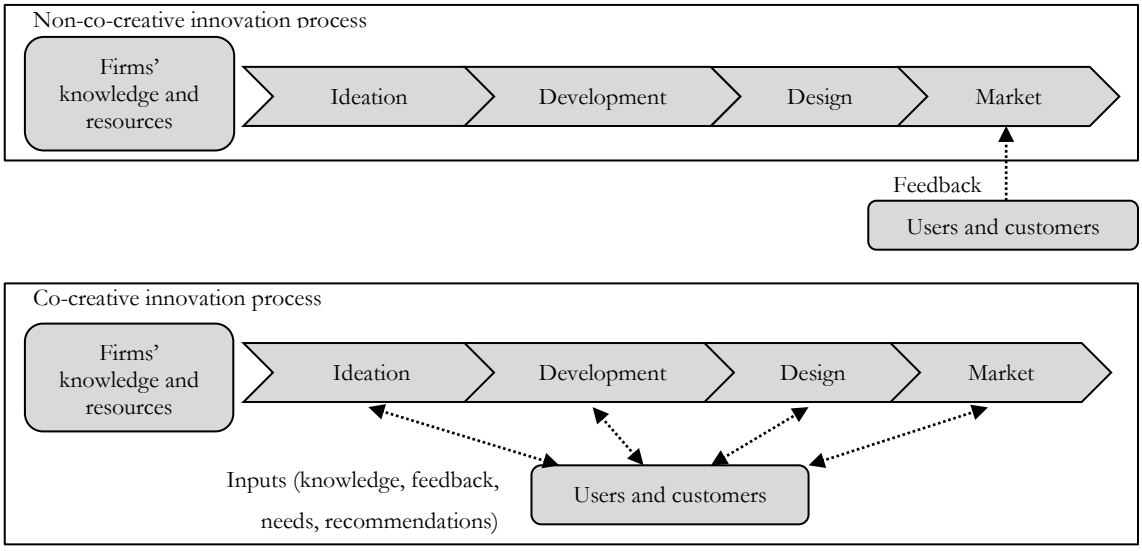

Figure 1. A comparison of the *non-co-creative* and the *co-creative innovation process*

What is in it for the users?

So far in this section, the focus has been on the underlying reasons of firm interaction and engagement with users and other external actors, however, no explanation has been provided on why these communities want to co-create with firms. As these factors draw on the nature of the user communities and their existence, further understanding of this can be extremely helpful for firms currently implementing Open Innovation strategies.

According to Zare et al. (2018), the determinants of interest in co-creation from the consumer side are first divided into two different strings: *Individual related drivers* and *Product related drivers*. Focusing on the former, the following conclusions were drawn:

- learning motivations: users want to engage in co-creation processes to learn about products and technologies, and exchange information with peers and firms. Acquiring added information and gaining new skills are considered benefits of this approach.
- social motivations: the creation of relationships within the community and firm, insertion into new networks, and feeling of belonging are said to motivate participation in co-creation activities.
- personal motivations: fame/reputation and authority create incentives to participate in these processes, with some firms even promoting initiatives capable of further igniting this factor (status level, rewarding systems, prizes, etcetera).
- hedonic motivations: on another note, pure fun and enjoyment can also be motivational for users. Participation in these activities can be seen as stimulating and entertaining for some users.
- monetary motivations: lastly, some firms can provide monetary incentives for the users to participate in co-creation activities (money prizes, products/services). However, this practice can wrongfully attract users without sufficient knowledge of the products/services.

Besides these motivations, it is also signalled as inhibitors of the process the *time and energy* required to take part in the co-creation processes (if too demanding, can restrict the number of users interested and willing to participate)(Zare et al., 2018); and the *risk of discredit* which occurs when the users are afraid of losing IPR, being used by the firms, or being ridiculed by their ideas. As such, the firms must guarantee the co-creation processes are attractive and

secure to the users willing to participate (Antorini & Muñiz, 2013; Rayna & Striukova, 2015; Zhang et al., 2018).

Additionally, it is mentioned that some user profiles are more desirable than others to engage in co-creation activities (Schütz et al., 2019; Oertzen et al., 2020; Y. Wang et al., 2020), such as *Innovation leaders* – suggest ideas for new products/services, avant-garde, and very active in the communities –, *Product Comparers* – demanding users, constantly compare the products with those of rival companies, highlighting weak and strong features on both sides –, and lastly, *Product Critics* – mostly intervene to point out problems and disappointments, very concerned with quality improvement (Y. Wang et al., 2020). However, it is still important to ensure these accurately represent the target client (Oertzen et al., 2020), namely, by including *Ordinary users* in these activities (Magnusson, 2009; Abbate et al., 2019).

How co-creation activities are conducted also has implications on the users' willingness to participate and co-create with a firm (Ardichvili, 2008; Verleye, 2015). In addition, firms' characteristics such as previous co-creation experience, product knowledge, and the industry of the product/service that is being co-developed, are influential factors for the willingness to participate in co-creation activities (Zare et al., 2018), therefore firms may have to adapt to benefit from co-creation processes (Cambra-Fierro et al., 2018; Y. Wang et al., 2020).

3. Materials and methods

The main goal of this study is to understand the impact of the engagement between firms and user communities, on innovation outputs (both in quantity, and type – product, process, marketing, or organisational). The conceptual model that serves as the basis of the study is displayed in Figure 2. The main hypotheses to be assessed through econometric estimations are the following:

H 1: Firms' engagement with user communities increases innovation propensity in general
H 1.1: Firms' engagement with user communities increases product innovation propensity
H 1.2: Firms' engagement with user communities increases process innovation propensity
H 1.3: Firms' engagement with user communities increases marketing innovation propensity
H 1.4: Firms' engagement with user communities increases organisational innovation propensity

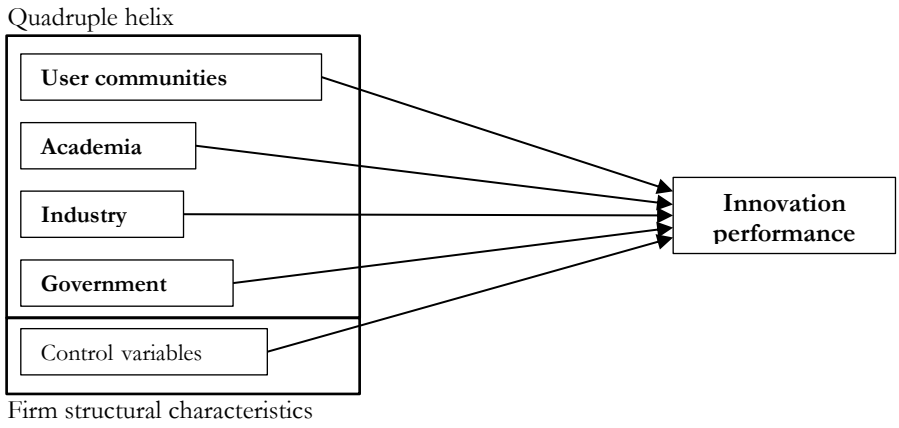

Figure 2. Conceptual model

The conceptual model is largely grounded in extant theory. Table 1 compiles the identified determinants of firms' innovation performance. The first four rows are related to previous evidence about the role of each of the helices in innovative performance, the last four relate to firms' structural characteristics, which must be considered in the model given their importance in the innovation performance.

Table 1. Determinants of firms' innovation performance

Determinants	**Articles reviewed**
Interaction with User communities	Carayannis and Campbell, 2012; Prause and Thurner, 2014; Schütz et al., 2019; and Costa et al., 2021
Interaction with Academia	Carayannis and Campbell, 2012; Guzzini and Iacobucci, 2017; Kobarg et al., 2017; and Atta-Owusu et al., 2021
Interaction with Industry	Carayannis and Campbell, 2012; Stejskal et al., 2018; Basit, 2021; and Damioli et al., 2018
Interaction with Government	Carayannis and Campbell, 2012; Afzal et al., 2018; Afcha and Lucena, 2022
Human Capital intensity	Basit, 2021; Costa et al., 2021; and Odei et al., 2021; Afcha and Lucena, 2022
International trade	Geng and Kali, 2021; Shu and Steinwender, 2019; Kampik and Dachs, 2011; and Odei et al., 2021
Size	Hashi and Stojčić, 2013; Basit, 2021; Kampik and Dachs, 2011; and Costa et al., 2021
Technological regime	Costa et al., 2021; Doran and Jordan, 2016; Basit, 2021; and Kampik and Dachs, (2011).

To test the proposed hypotheses the study will resort to a quantitative methodology. This methodology complies with the existing stream of innovation studies that follow a deductive logic, formulating hypotheses based on existing literature that is then assessed using secondary data (Faems, 2020). The use of quantitative research methods allows to generalise the validated hypothesis to other similar situations and allows other academics to replicate the study. Additionally, this method provides objectivity, clarity, and precision given the neutrality of the researcher, and reduced degree of subjectivity of the data (Basias & Pollalis, 2019).

The data used for analysis was collected from Portuguese firms (referring to the period between 2016 and 2018) by Direção-Geral de Estatísticas da Educação e Ciência and Instituto Nacional de Estatística, in 2020, as part of the Community Innovation Survey (CIS) conducted in 2018. The sample is comprised of 15 876 firms, however, during the analysis only 13 701 firms (86%) will be considered, to level out non-existent answers. The sample was arranged based on simple random sampling, while simultaneously fulfilling specific criteria to assure the quality of the results and an accurate representation of the population. The evidence was retrieved from the Portuguese CIS of 2018 microdata (Direção-Geral de Estatísticas da Educação e Ciência & Instituto Nacional de Estatística, 2020).

3.1. Dependent variable(s)

To measure the innovation performance of firms, we will consider 5 dummy variables: *innovation in general*, *product innovation*, *process innovation*, *organisational innovation*, and *marketing innovation*, with the variable *innovation* being a proxy derived from the remaining ones, allowing a more comprehensive analysis, as the variable encompasses every innovation type. The measurement of innovation output included in the CIS 2018 follows the Oslo Manual recommendations (OECD/Eurostat, 2005; Andersson et al., 2021). These variables are commonly used in innovation studies using CIS data, namely by Tavassoli and Karlsson (2015), Crescenzi and Gagliardi (2018), Costa et al. (2018), and Costa and Matias (2020).

3.2. Explanatory variables

As explanatory variables, we shall consider the interaction between firms and the four actors of the Quadruple Helix (Carayannis & Campbell, 2012).

Our key variable is the interaction with user communities, which is measured through the engagement in co-creation processes led by firms together with the users (Prause & Thurner, 2014; Schütz et al., 2019). This variable takes the value of 1 if the firm has engaged in co-creation processes with user communities, and 0 in all other cases. The use of this engagement as a proxy for the interaction between firms and user communities is not new in studies using CIS data, such as Costa et al. (2021).

Concerning the Academia helix, to quantify this interaction we considered the cooperation related to innovation with Universities or Public research institutes, being 1 if the firm answers positively and 0 in all other cases. This variable is commonly used in innovation studies using the CIS databases, such as Guzzini and Iacobucci (2017), Kobarg et al. (2017), and Atta-Owusu et al. (2021).

Regarding the interaction with other firms (Industry helix), the variable follows the same logic as the previous one, but now concerns cooperation with other firms. These firms can be either national, foreign, clients, suppliers, competitors, or even from the same group as the firm concerned, taking the value of 1 if the firm cooperates with any external firm, and 0 if otherwise. Similarly, the use of this variable is not new in studies that rely on the CIS database, as Stejskal et al. (2018), Basit (2021), and Damioli et al. (2018).

In terms of interaction with the Government, we will quantify this by the means of receiving financial support from public entities (either local, regional, central, or at a European level), taking the value of 1 in this case, and 0 in all others. This proxy indicator is not new to innovation studies, such as seen in Afzal et al. (2018), Kampik and Dachs (2011), and (Afcha & Lucena, 2022).

3.3. Control variables

For statistical control, a set of control variables capable of influencing the firms' innovation performance will be accounted.

3.3.1. Human Capital intensity

This is a multinomial variable that measures the percentage of human capital, following the CIS scale indicated in Table 2. We expect this variable to have a positive impact on innovation performance (Colapinto & Porlezza, 2011; Farace & Mazzotta, 2015; Papa et al., 2018; Afzal et al., 2018; Gur, 2020). The role of human capital in innovation performance is generally accepted by academics and commonly used as a control variable, namely, in studies using the CIS data: Basit (2021), Costa et al. (2021), and Odei et al. (2021). Moreover, this variable is commonly measured through the percentage of personnel with at least undergraduate education (Afcha & Lucena, 2022).

3.3.2. International trade

This is a dummy variable that takes the value of 1 for exporting firms, and 0 for non-exporting firms. International trade can have ambiguous effects on innovation performance, the expansion of the market size can create a positive effect, but the increased market competition can create some constraints for less productive firms (Geng & Kali, 2021; Shu & Steinwender, 2019). This control variable is commonly used in innovation studies, such as Kampik and Dachs (2011), and Odei et al. (2021).

3.3.3. Size

This variable is based on the CIS original scale, small (1), medium (2), and large (3) according to the European Innovation Scoreboard scale (European Commission, 2020). Larger firms tend to have better access to funding, and, consequently, are capable of having larger

investments in innovation processes but not necessarily produce more innovations (Hashi & Stojčić, 2013). This variable is largely used in similar studies to this, as seen in Basit (2021), Kampik and Dachs (2011), and Costa et al. (2021).

3.3.4. Technological regime

In this variable, we performed some basic mathematical transformations, to group the various sectors according to their technical regime (from 1 to 4), instead of using the CAE classification (Costa et al., 2021). The use of this variable is broadly accepted in innovation studies, to control sector-specific effects on innovation performance (Doran & Jordan, 2016), this is even more relevant concerning CIS-based studies such as Basit (2021), and Kampik and Dachs (2011).

Table 2 describes the variables used for the econometric estimations.

Table 2. Variable description

Variable	Description	Measurement
INNOV(1)	Having performed at least one type of innovation	Binary
PROD_I(2)	Having performed product innovation	Binary
PROC_I(3)	Having performed process innovation	Binary
ORG_I(4)	Having performed organisational innovation	Binary
MARK_I(5)	Having performed marketing innovation	Binary
INTER_IND(6)	Interaction with Industry	Binary
INTER_ACAD(7)	Interaction with Academia	Binary
INTER_GOV(8)[3]	Interaction with Government	Binary
INTER_COMM(9)	Interaction with User Community	Binary
H_CAP(10)	Human Capital intensity	Scale (1 = "0%"; 2 = ">=1% to <5%" ; 3 = ">=5% to <10%" ; 4 = ">=10% to <25%" ; 5 = ">=25% to <50%" ; 6 = ">=50% to <75%" ; 7 = ">=75%")
EXP(11)	Exporting company	Binary
SIZE(12)	Nr. of employees	Scale (1 = small; 2 = medium; 3 = large)

[3] Measured by being a beneficiary of public funding

TECH(13)	Technological Regime, according to Costa et al. (2021)	Scale (1 = supplier dominated; 2 = scale intensive; 3 = specialized supplier; 4 = science-based

3.4. Exploratory analysis

As displayed in **Table 3**, the sample is diverse in terms of sector and industry. Likewise, the percentage of firms interacting with user communities also has a high degree of variability. It is important to highlight the big percentage of *Information and communication activities, Manufacturing*, and *Consultancy, scientific and technical activities* firms (31,86%, 25,57%, and 21,78%, respectively) engaging with user communities. By contrast, *Water collection, treatment, and distribution; sewerage, waste management and remediation activities,* and *Real estate activities* firms display residual values of engagement with the user communities. This variability seems to indicate that the firms' sector is a determining factor for this interaction. Overall, almost 17% of all inquired firms indicate they collaborate with user communities, revealing the prevalence of the fourth helix in the Portuguese innovation ecosystem.

Table 3. Number of firms by sector, entire sample vs interacting with User communities

Sector	All		Interaction with User Community	
	N	%[4]	N	%[5]
Manufacturing	4216	30,77	1078	**25,57**
Wholesale and retail trade; repair of motor vehicles and motorcycles	2355	17,19	181	7,69
Construction	1441	10,52	202	14,02
Administrative and support service activities	863	6,30	134	15,53
Consultancy, scientific and technical activities	863	6,3	188	**21,78**
Accommodation and food service activities	682	4,98	72	10,56
Transportation and storage	630	4,60	56	8,89
Information and communication activities	499	3,64	159	**31,86**
Human health and social work activities	430	3,14	33	7,67
Agriculture, farming of animals, hunting and forestry	376	2,74	27	7,18
Water collection, treatment, and distribution; sewerage, waste management and remediation activities	271	1,98	18	6,64
Financial and insurance activities	261	1,90	40	15,33
Real estate activities	229	1,67	16	6,99
Arts, entertainment, sports, and recreation activities	164	1,20	20	12,20
Other service activities	144	1,05	18	12,50
Education	138	1,01	16	11,59
Mining and quarrying	98	0,72	11	11,22
Electricity, gas, steam, cold and hot water, and cold air	41	0,30	4	9,76
Total	13701	100	2273	16,59[6]

[4] in the total number of respondents

[5] in the total of respondents that interact with User Communities

[6] percentage in the total number of respondents

Table 4. Innovation performance and structural characteristics of firms by interaction with the User Community

Interaction with User Community	N	Product Innovation		Process Innovation		Organisational Innovation		Marketing Innovation		Science-based Firms		Highly-skilled human capital[7]		Exporting firm	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
Yes	2273	1388	**61,06**	1116	49,10	1045	45,97	787	34,62	187	8,23	293	12,89	1735	**76,33**
No	11428	2305	20,17	1758	15,38	2121	18,56	1460	12,78	575	5,03	904	7,91	5927	51,86
Total	13701	3693	-	2874	-	3166	-	2247	-	762	-	1197	-	7662	-

Table 5. Collaboration with external partners for innovation development

Interaction with User Community	N	No collaboration, only the firm		The firm in collaboration with other firms or organisations		The firm adapts or modifies processes developed by other firms or organisations		With other organisations	
		N	%	N	%	N	%	N	%
Yes	2273	1233	**54,25**	729	32,07	218	9,59	122	**5,37**
No	11428	2311	20,22	1215	10,63	312	2,73	294	2,57
Total	13701	3544	-	1944	-	530	-	416	-

Table 6. Innovation performance and characteristics by helix interaction

Interaction with	N	Product Innovation		Process Innovation		Organisational Innovation		Marketing Innovation		Science-based firms		Highly-skilled human capital		Exporting firm	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
User Community	2273	1388	61,06	1116	49,10	1045	45,97	787	34,62	187	8,23	293	12,89	1735	76,33
Government	2417	1167	48,28	959	39,68	922	38,15	705	**29,17**	173	7,16	280	11,58	1698	70,25
Academia	652	493	75,61	418	64,11	391	59,97	292	44,79	103	15,8	145	22,24	510	78,22
Industry	1156	878	**75,95**	715	61,85	696	60,21	536	46,37	158	13,67	236	20,42	873	75,52

[7] firms reaching the top standard in terms of undergraduates among their personnel (>75%)

Table 7. Innovation performance and structural characteristics by firm size

Firm size	N	Product Innovation		Process Innovation		Organisational Innovation		Marketing Innovation		Science-based firms		Highly-skilled human capital		Exporting firm		Interaction with User Community	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Small	9451	2127	22,51	1633	17,28	1845	19,52	1293	13,68	500	5,29	821	8,69	4870	**51,53**	1456	15,41
Medium	3509	1212	34,54	985	28,07	1039	29,61	750	21,37	192	5,47	307	8,75	2324	**66,23**	656	18,69
Large	741	354	47,77	256	34,55	282	38,06	204	27,53	70	9,45	69	9,31	468	**63,16**	161	21,73
Total	13701	3693	-	2874	-	3166	-	2247	-	762	-	1197	-	7662	-	2273	-

Table 8. Innovation performance and structural characteristics by technical regime

Technological regime	N	Product Innovation		Process Innovation		Organisational Innovation		Marketing Innovation		Highly-skilled human capital		Exporting firm		Interaction with User Community	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
Supplier dominated	7933	1987	25,05	1500	18,91	1726	21,76	1307	16,48	310	**3,91**	4408	55,57	1088	13,71
Scale intensive	2699	734	27,02	576	21,34	574	21,27	372	13,78	161	5,97	1539	57,02	556	**20,60**
Specialised supplier	2307	641	27,79	542	23,49	584	25,31	371	16,08	459	19,9	1305	56,57	442	19,16
Science based	762	331	**43,44**	256	33,6	282	37,01	197	25,95	267	**35,04**	410	53,81	187	**24,54**
Total	13701	3693	-	2874	-	3166	-	2247	-	762	-	1197	-	7662	-

From **Table 4** we can establish a positive connection between the interaction with user communities and innovation performance, given the overall improvement across the 4 innovation indicators. This is particularly significant for product and process innovations, and less relevant in marketing innovation. It is also worth highlighting that the propensity of interacting with user communities seems to be slightly higher in firms with highly skilled human capital, and significantly higher in firms with a presence in international markets. The typical Portuguese firm engaging with user communities creates product and process innovations, exports products/services, is not *science-based,* and has low human capital intensity.

In **Table 5** we can observe an interesting phenomenon, firms that do not have partners for innovation development, are the ones that most interact with user communities (54,25%). This apparent paradox can be explained by a substitution assumption (instead of complementary) between the interaction with user communities (consumers) and other firms/organisations (value chain). Firms with partners for innovation development seem to neglect user communities, as they have other external sources of input. This can be further explained by the difficulty of understanding a different type of partner; the communication between firms is easier than with users, as they have different objectives and perspectives.

Table 6 displays the characteristics of firms that interact with each of the innovation ecosystem actors. From this data, we can highlight the high influence of the interaction with other firms (Industry) on innovation performance, and the modest influence of the interaction with Governments – this can be explained given that most public incentives/subsidies relate only to product or process innovation, hence, the minimal impact of this helix on marketing innovation. In addition, the interaction between science-based firms and Academia is surprisingly low, given the knowledge intensity of these firms and the established benefits of this connection. Lastly, it is important to note that the vast majority of firms interacting with one of the actors are firms present in international markets, highlighting the importance of these interactions for the firms' competitiveness.

In **Table 7** we can contrast the differences between small, medium, and large firms. There is a clear significant improvement in innovation performance in larger firms, namely regarding product innovation, with almost 50% of large firms developing this type of innovation comparatively with the 22% of small firms. On the other hand, the proportion of science-based firms, highly-skilled human capital, exporting firms, and interaction with

user communities do not vary substantially according to the size of the firm, although, the indicators have a slightly better performance on large firms.

Lastly, in **Table 8** we can see the differences in the several indicators according to the technological regime of firms. Science-based firms have significantly better innovation performance on all types of innovations – with almost half of the firms developing product innovations, as for the remaining firms, do not have a high disparity among the four innovation indicators. Concerning the human capital indicator, as expected, the science-based firms have a significant value (35,04%) opposing to the supplier-dominated and scale-intensive firms with 3,91% and 5,97%, respectively.

3.5. Descriptive statistics

Table 9 reports the descriptive statistics and zero-order correlations of the variables mentioned above. Innovative firms account for 27% of the sample, *Product innovation* is the biggest type of innovation, followed by *Organisational innovation* (23%), *Process innovation* (21%), and, lastly, *Marketing innovation* (16%). The sampled firms show low levels of interaction with the Industry and Academia (only 8 and 5%, respectively), and slightly higher indicators for the interaction with Government and User communities (18 and 17%, respectively). In addition, more than half of the firms are present in international markets (56%).

The correlation appears as significant for most of the pairings with moderate intensity. The Variance Inflation Factor also guarantees the inexistence of multicollinearity.

In **Table 10**, the added value of interacting with user communities becomes clear, with the first subgroup surpassing the second in every innovation performance variable, especially in product (61% vs 20%) and process innovation (49% vs 15%). In addition, firms that interact with user communities also interact more with the Industry, Academia, and Government than those that do not. In terms of size, human capital intensity and technological regime both subgroups show similar results, with slightly higher indicators in the first subgroup. It is also important to highlight that 3 in every 4 firms that interact with user communities have a presence in international markets, opposing to half of the other subgroup. Regarding the correlations between variables, with the exception of the high correlation among innovation performance variables (given INNOV(1) was created by merging the other 4) and the high correlation between interaction with Academia and Industry, all other coefficients are below 0,372.

Table 9. Summary statistics and correlation table

Variables	Min	Max	Mean	SD	VIF	1	2	3	4	5	6	7	8	9	10	11	12	13
INNOV(1)	0	1	0,27	0,443	-	1												
PROD_I(2)	0	1	0,27	0,444	-	0,782**	1											
PROC_I(3)	0	1	0,21	0,407	-	0,806**	0,630**	1										
ORG_I(4)	0	1	0,23	0,422	-	0,779**	0,564**	0,599**	1									
MARK_I(5)	0	1	0,16	0,370	-	0,710**	0,529**	0,539**	0,597**	1								
INTER_IND(6)	0	1	0,08	0,278	1,679	0,337**	0,335**	0,305**	0,267**	0,246**	1							
INTER_ACAD(7)	0	1	0,05	0,213	1,652	0,250**	0,245**	0,237**	0,195**	0,171**	0,609**	1						
INTER_GOV(8)	0	1	0,18	0,381	1,130	0,217**	0,223**	0,213**	0,165**	0,160**	0,257**	0,287**	1					
INTER_COMM(9)	0	1	0,17	0,372	1,096	0,310**	0,343**	0,308**	0,242**	0,219**	0,230**	0,171**	0,146**	1				
H_CAP(10)	1	7	3,39	1,859	1,238	0,199**	0,205**	0,149**	0,177**	0,169**	0,204**	0,179**	0,133**	0,107**	1			
EXP(11)	0	1	0,56	0,496	1,066	0,194**	0,205**	0,175**	0,139**	0,152**	0,120**	0,100**	0,134**	0,183**	0,109**	1		
SIZE(12)	1	3	1,36	0,583	1,072	0,160**	0,162**	0,138**	0,134**	0,115**	0,191**	0,177**	0,122**	0,050**	0,156**	0,118**	1	
TECH(13)	1	4	1,70	0,938	1,175	0,076**	0,074**	0,079**	0,068**	0,027**	0,117**	0,110**	0,019*	0,085**	0,372**	0,002	0,016	1

**Correlation is significant at a 0.01 level (two-tailed). *Correlation is significant at a 0.05 level (two-tailed).

Table 10. Descriptive statistics of the sample

	Interaction with User Community				No interaction with User Community			
Variables	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
INNOV(1)	0	1	**0,58**	0,494	0	1	0,21	0,405
PROD_I(2)	0	1	**0,61**	0,488	0	1	0,20	0,401
PROC_I(3)	0	1	**0,49**	0,500	0	1	0,15	0,361
ORG_I(4)	0	1	**0,46**	0,498	0	1	0,19	0,389
MARK_I(5)	0	1	**0,35**	0,476	0	1	0,13	0,334
INTER_IND(6)	0	1	**0,23**	0,419	0	1	0,06	0,230
INTER_ACAD(7)	0	1	**0,13**	0,336	0	1	0,03	0,174
INTER_GOV(8)	0	1	**0,30**	0,459	0	1	0,15	0,359
INTER_COMM(9)	1	1	1,00	0,000	0	0	0,00	0,000
H_CAP(10)	1	7	**3,84**	1,829	1	7	3,30	1,852
EXP(11)	0	1	**0,76**	0,425	0	1	0,52	0,500
SIZE(12)	1	3	1,43	0,622	1	3	1,35	0,574
TECH(13)	1	4	1,88	0,994	1	4	1,66	0,923

4. Econometric analysis

4.1. Estimations and results

Through the following estimations, we aim to measure the impact of the interaction between firms and user communities on the different innovation outcomes. We chose to perform binary logistic regressions in order to properly assess the impact, given the characteristics of the dependent variables. The significance of the variables was assessed through Likelihood Ratio Tests (Annex A). Equation 1 represents the general model and Table 11 provides the results of the logit regressions.

Equation 1. Econometric model

$$innov_i = \beta_1 + \beta_2 inter\_comm_i + \beta_3 inter\_ind_i + \beta_4 inter\_acad_i + \beta_5 inter\_gov_i + \beta_6 h\_cap_i + \beta_7 exp_i + \beta_8 size_i + \beta_9 tech_i + \varepsilon_i$$

The coefficients for the variable INTER_COMM(9) are consistent and positive across all types of innovation, particularly in terms of product and process innovation, with statistical significance (p-value < 0,01). These results confirm that the interaction between firms and user communities is beneficial for firms, as it fosters their innovation performance.

Similarly, interacting with other firms, measured by the variable INTER_IND(6), also shows consistent and positive effects on innovation outcomes, namely on product innovation. This interaction has a greater effect on general, product, organisational, and marketing innovation, in comparison with the interaction with user communities.

Concerning the interaction between firms and universities or research institutes, measured by the variable INTER_ACAD(7), the results are not very consistent (not statistically significant for product and organisational innovation and with a negative impact on marketing innovation). This demonstrates the fragility of this cooperation and the lack of fruitful interactions between firms and the Academia.

At last, the interaction with Government, measured by the variable INTER_GOV(8), shows consistent positive effects across all types of innovation, with higher relevance for process and product innovation. These results indicate that public funding of innovation has a significant impact on firms' innovation performance.

Table 11. Estimation of the innovation performance

	Model 1				
Variables	INNOV(1)	PROD_I(2)	PROC_I(3)	ORG_I(4)	MARK_I(5)
	Exp(B)	Exp(B)	Exp(B)	Exp(B)	Exp(B)
INTER_COMM(9)	3,669***	4,496***	3,682***	2,654***	2,479***
	(0,053)	(0,054)	(0,054)	(0,053)	(0,057)
INTER_IND(6)	4,859***	4,845***	3,356***	3,064***	2,870***
	(0,091)	(0,093)	(0,087)	(0,084)	(0,087)
INTER_ACAD(7)	1,311**	1,186	1,288**	1,056	-0,888
	(0,125)	(0,126)	(0,116)	(0,112)	(0,113)
INTER_GOV(8)	1,797***	1,860***	1,894***	1,500***	1,545***
	(0,055)	(0,055)	(0,056)	(0,055)	(0,060)
H_CAP(10)	1,163***	1,178***	1,083***	1,161***	1,217***
	(0,013)	(0,013)	(0,014)	(0,013)	(0,015)
EXP(11)	1,761***	1,845***	1,721***	1,417***	1,733***
	(0,046)	(0,047)	(0,050)	(0,046)	(0,054)
SIZE(12)	1,361***	1,377***	1,316***	1,303***	1,238***
	(0,036)	(0,037)	(0,038)	(0,036)	(0,040)
TECH(13)	-0,969	-0,953*	1,043	-0,975	-0,847***
	(0,025)	(0,025)	(0,026)	(0,025)	(0,028)
Constant	-0,060***	-0,054***	-0,050***	-0,068***	-0,043***
	(0,078)	(0,079)	(0,083)	(0,077)	(0,089)
-2 Log likelihood	13156,551	12909,444	11854,279	13161,061	10804,392

*** p-value < 0,01, ** p-value <0,05, * p-value <0,1

Regarding the control variables human capital intensity, exporting firm, and size, these show similar results with consistent and positive effects across all types of innovations. The intensity of human capital has a more significant impact on organisational innovation, whereas the presence of the firm in international markets has a slightly lower impact on this type of innovation. The size variable also demonstrates positive and consistent results across all types of innovation (also showing a slightly lower effect on organisational innovation), indicating that larger firms have a higher propensity to innovate.

Remarkably, the variable TECH(13) indicates the firms' technological regime has a negative effect on general, product, organisational, and marketing innovation. In addition, the variable is not statistically significant for general, process, and organisational innovation. This suggests that the firms' sector is not a decisive factor in their innovation performance.

In sum, these results reveal that the Portuguese innovation system is characterised by the Quadruple Helix model, further reinforcing the value of implementing Open Innovation practices. However, the interactions with these actors do not uniformly foster all types of innovation. Regarding the interaction with user communities, it is positive and consistent across all types of innovation, with an increased effect on product and process innovation.

4.2. Moderation effects

A moderator is a variable capable of influencing the relationship between another independent variable and a dependent variable, by means of direction and/or intensity. According to Baron and Kenny (1986), the moderator should simultaneously function as an independent variable, and this way, there will be three causal paths affecting the dependent variable: the independent variable – as a predictor, the other independent variable – as a moderator, and the interaction between the two.

In the context of this study, the moderation effect of Human Capital intensity can be illustrated in Figures 3 and 4, with Human Capital intensity being a moderator of the relationship between a firm interacting with user communities and their innovative performance.

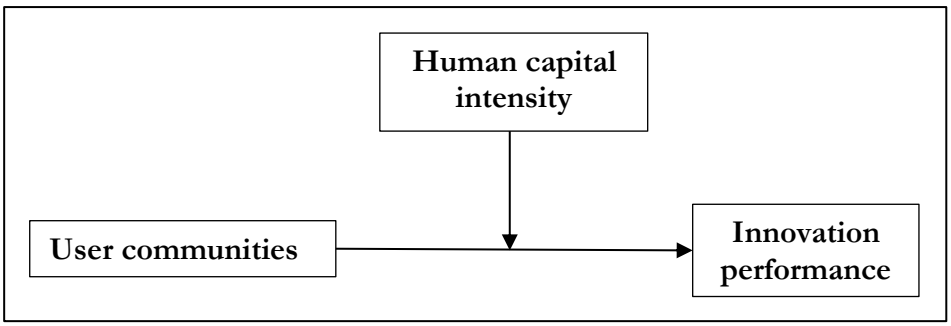

Figure 4. Moderation model

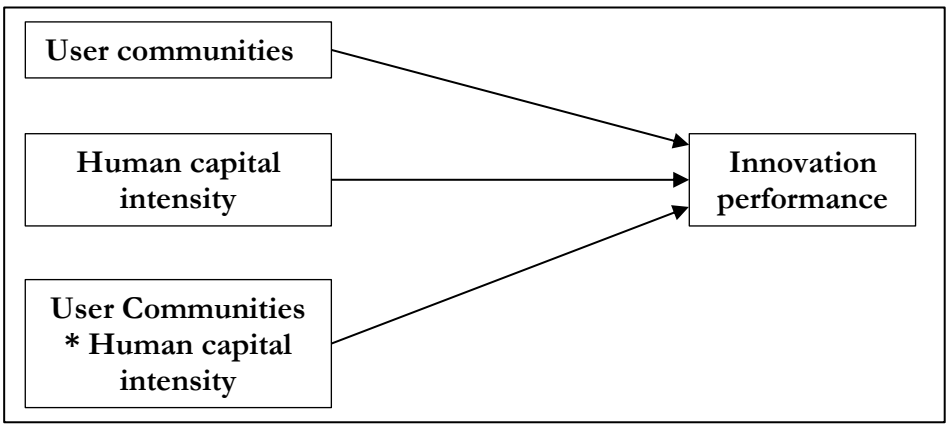

Figure 3. Moderation effect model

The acquisition of external knowledge and successful integration with the internal one is key for innovative firms (Chesbrough, 2003), which is highly dependent on the absorptive capacity of the firm (West & Bogers, 2014). Absorptive capacity can also have drastically different effects on external collaborations (West & Bogers, 2014). On one hand, it may stimulate these collaborations; on the other hand, it may reduce the need to have collaborations.

As demonstrated in **Model 2** from Table 12, the sign of the coefficient of the interaction term (human capital intensity and interaction with user communities) is negative, indicating these are substitute characteristics. This means that the marginal effects on innovation performance of highly-skilled employees are not as relevant to firms that interact with user communities. However, this conclusion is contradictory to a study by Dahlin et al., in 2019, in which they found that absorptive capacity had positive indirect effects on innovation through co-creation both in Sweden and Norway.

This result can be explained by the substitution effect between having the absorptive capacity and having the need for external sources of knowledge, meaning, that firms with greater absorptive capacity do not engage with user communities, as they do not find their knowledge as beneficial. In addition, the not invented here (NIH) syndrome can further foster this effect, as human resources can be resistant to external knowledge and ideas (Zhao et. al, 2015). This prevents the company from fully benefiting from users' knowledge, instead of taking advantage of the complementary approaches.

4.3. Robustness check

To further validate the results presented in the previous section, we conducted a robustness check through the 7 models showcased in Table 12.

In **Model 3** we applied the same logic as before, but now with the variable EXP(11). In this case, the term interaction also has a negative coefficient, indicating that these characteristics are substitutes for each other. For both models, the regression included general innovation and product innovation as dependent variables. Given the consistent results, for the remaining models, we are only displaying the regression for general innovation.

In **Model 4** we broaden the variable of interaction with user communities, to also include mass customisation, and personalisation processes (Rayna & Striukova, 2015). This change did not significantly impact the estimations in comparison with Model 1, further validating the results obtained.

For **Model 5** we included the variable BARRIERS, which is a dummy variable that indicates if a firm had encountered any difficulty that negatively impacted the decision to start or implement innovation activities. The coefficient of this variable is not statistically significant;

however, it is worth noting that, paradoxically, this value is positive. This counter-intuitive result is consistent with other studies using CIS data (Costa et al., 2018).

In **Model 6** we added INVEST, a multinomial variable that ranges from 0 to 3 according to the firms' investment (absolute values). With the addition of this value, the coefficients of the values did not present significative changes, however, the variable SIZE(12) became statistically non-significant. This indicates that the dimension of a firm and the investment made by them are substitutes. Meaning, that an SME with adequate funding and investment, can be as innovative as a large company.

In **Model 7** we included CHANNELS, a dummy variable that measures if the firm used any channel as a source of knowledge (including scientific journals, crowd-sourcing, open-source software, or reverse engineering). This variable is statistically significant and has a high coefficient (4,730).

At last, in **Model 8** we broaden the variable that measures the interaction with the Government helix, to also include receiving tax credits and subsidies. This did not make substantial differences in the remaining variables and increased the coefficient of this variable (2,031).

In sum, it is important to highlight the consistency of the User Community, Industry, and Government interaction across all models, further supporting the value of these helixes for firms' innovation and reinforcing the results obtained for the previous models.

Table 12. Robustness check summary

Variables	Model 2		Model 3		Model 4	Model 5	Model 6	Model 7	Model 8
	INNOV(1)	PROD_I(2)	INNOV(1)	PROD_I(2)	INNOV(1)	INNOV(1)	INNOV(1)	INNOV(1)	INNOV(1)
INTER_COMM(9)	5,126*** (0,119)	6,852*** (0,119)	4.674*** (0.101)	5,393*** (0,101)	-	3,670*** (0,053)	3,584*** (0,054)	3,172*** (0,054)	3,647*** (0,053)
INTER_IND(6)	4,860*** (0,091)	4,844*** (0,092)	4.865*** (0.091)	4,848*** (0,093)	4,651*** (0,092)	4,852*** (0,091)	4,343*** (0,092)	4,423*** (0,091)	4,579*** (0,092)
INTER_ACAD(7)	1,342** (0,124)	1,193 (0,125)	1,307** (0,125)	1,184* (0,126)	1,291** (0,125)	1,305** (0,125)	1,299** (0,126)	1,254** (0,124)	1,241** (0,125)
INTER_GOV(8)	1,795*** (0,055)	1,858*** (0,055)	1,801*** (0,055)	1,862*** (0,055)	1,741*** (0,055)	1,799*** (0,055)	1,562*** (0,056)	1,566*** (0,055)	-
H_CAP(10)	1,185*** (0,014)	1,206*** (0,014)	1,163*** (0,013)	1,178*** (0,013)	1,120*** (0,013)	1,163*** (0,013)	1,123*** (0,013)	1,098*** (0,013)	1,159*** (0,013)
EXP(11)	1,760*** (0,046)	1,844*** (0,47)	1.870*** (0.051)	1.933** (0.052)	1,756*** (0,047)	1,761*** (0,046)	1,591*** (0,047)	1,594*** (0,047)	1,698*** (0,046)
SIZE(12)	1,360*** (0,036)	1,376*** (0,037)	1,362*** (0,036)	1,377*** (0,037)	1,311*** (0,037)	1,362*** (0,036)	1,052 (0,195)	1,293*** (0,037)	1,299*** (0,037)
TECH(13)	-0,972 (0,025)	-0,956* (0,025)	-0,970 (0,025)	-0,953* (0,025)	-0,967 (0,025)	-0,970 (0,025)	-0,974*** (0,300)	-0,992 (0,025)	-0,964 (0,025)
INTER_COMM(9)* H_CAP(10)	-0,914*** (0,029)	-0,892*** (0,029)	-	-	-	-	-	-	-
INTER_COMM(9)* EXP(11)	-	-	-0.717*** (0,119)	-0.778** (0,119)	-	-	-	-	-
INTER_COMM2	-	-	-	-	3,837*** (0,045)	-	-	-	-
BARRIERS	-	-	-	-	-	1,018 (0,051)	-	-	-
INVEST	-	-	-	-	-	-	1,563*** (0,023)	-	-
CHANNELS	-	-	-	-	-	-	-	4,730*** (0,073)	-
INTER_GOV2	-	-	-	-	-	-	-	-	2,031*** (0,049)
Constant	-0,056*** (0,081)	-0,049*** (0,083)	-0,057*** (0,079)	-0,052*** (0,081)	-0,050*** (0,080)	-0,059*** (0,087)	-0,050*** (0,080)	-0,024*** (0,097)	-0,061*** (0,078)
-2 Log likelihood	13146,713	12893,923	13148,731	12904,997	12818,166	13155,337	12765,226	12569,439	13065,764

*** p-value <0,01, ** p-value <0,05, *** p-value <0,1

5. Conclusions

5.1. Theoretical and empirical findings

With the emergence of Industry 5.0 and the rising awareness regarding societal issues among the Quadruple Helix model actors, firms have an increased incentive to engage with user communities to successfully keep up with this transformation and accustom the society's needs and wants. With this, interacting with user communities and receiving their valuable knowledge and feedback as innovation inputs becomes even more relevant, allowing the firms to design and create human-centred products and services. Furthermore, it is already possible to see the emergence of this paradigm in several actors of the innovation ecosystem which does further encourage firms to also adapt their innovation processes and gather new knowledge sources.

This dissertation was conducted to determine if the engagement between user communities and firms had a positive impact on their propensity to innovate. To further explore this result, this hypothesis was assessed for the several types of innovation. Upon the empirical research conducted, we can establish that the engagement between user communities and firms does foster their innovation performance (across all types of innovation, with increased impact on product and process innovation). The robustness analysis further confirmed this result.

The results also show the relevance of the remaining actors of the Quadruple Helix model and reinforce the benefits of these interactions regarding innovation outcomes. However, the fragility and lower effects of interacting with the Academia, indicate that these collaborations need to be improved to fully capitalise on them. In addition, the positive and consistent results for the interactions with other firms and the Government, demonstrate the need to further promote these connections, as a way to foster firms' innovation performance.

This study proves the meaningful role of the user communities in firms' innovation, as well as the presence of the Quadruple Helix model in the Portuguese innovation system. With the emerging paradigm of Industry 5.0, we predict this role will be increasingly meaningful and become a pivotal factor for firms' competitiveness.

5.2. Limitations and future research

This analysis used the CIS database, with 13701 Portuguese firms. As such, the results obtained may be only valid for the Portuguese innovation system. As future research avenues, this study could be replicated with CIS databases from other countries. Moreover, the financial data from the database presented several restrictions with a low number of valid observations, for this reason, financial factors were disregarded. Nevertheless, the incorporation of financial factors could bring information of interest to academics, practitioners, and policy makers.

It could be a useful option to further study the impact of engaging with user communities, through the perspective of radical or incremental innovations, in order to further comprehend the nature of the innovations. Furthermore, conducting a dynamic analysis can also be a viable option to better the impact of these interactions over time.

In terms of future research, we can also highlight studying the moderation effect of human capital on the relationship between a firm interacting with user communities and their innovative performance.

5.3. Policy recommendations

Given the obtained results, we can establish a positive relationship between the interaction with user communities and firms' innovation performance. As such, the promotion and enhancement of these interactions should be a priority for innovation policymakers. Firms must be aware of the need to interact with the user communities, as well as how to effectively promote them. In addition, financial incentives can also be effective in promoting this engagement.

Public policy can also have a decisive role to support firms as they adapt their processes and strategies for Industry 5.0. Implementing responsible innovation and CSR practices can lead to increased costs, and the benefits may not be immediate, consequently, it is important that firms have access to funding or incentives. Furthermore, from our analysis we can also conclude that public innovation funding generates a positive and consistent effect on firms' innovation outputs, reinforcing the importance of this instrument.

6. References

Abbate, T., Codini, A. P., & Aquilani, B. (2019). Knowledge co-creation in Open Innovation Digital Platforms: processes, tools and services. Journal of Business & Industrial Marketing, 34(7), 1434–1447. https://doi.org/10.1108/jbim-09-2018-0276

Afcha, S., & Lucena, A. (2022). R&D subsidies and firm innovation: does human capital matter? Industry and Innovation, 1–31. https://doi.org/10.1080/13662716.2022.2088334

Afzal, M. N. I., Mansur, D. D. K. B. H. M., Siddiqui, S., & Gope, J. (2018). A panel investigation of the triple helix (TH), quadruple helix (QH) relationship in ASEAN-5 economies. Journal of Innovation Economics & Management, n° 27(3), 97–122. https://doi.org/10.3917/jie.027.0097

Agostini, L., Nosella, A., & Filippini, R. (2017). Does intellectual capital allow improving innovation performance? A quantitative analysis in the SME context. Journal of Intellectual Capital, 18(2), 400–418. https://doi.org/10.1108/jic-05-2016-0056

Andersson, M., Kusetogullari, A., & Wernberg, J. (2021). Software development and innovation: Exploring the software shift in innovation in Swedish firms. Technological Forecasting and Social Change, 167, 120695. https://doi.org/10.1016/j.techfore.2021.120695

Antorini, Y. M., & Muñiz, A. M. (2013). The Benefits and Challenges of Collaborating with User Communities. Research-Technology Management, 56(3), 21–28. https://doi.org/10.5437/08956308x5603931

Aquilani, B., Piccarozzi, M., Abbate, T., & Codini, A. (2020). The Role of Open Innovation and Value Co-creation in the Challenging Transition from Industry 4.0 to Society 5.0: Toward a Theoretical Framework. Sustainability, 12(21), 8943. https://doi.org/10.3390/su12218943

Ardichvili, A. (2008). Learning and Knowledge Sharing in Virtual Communities of Practice: Motivators, Barriers, and Enablers. Advances in Developing Human Resources, 10(4), 541–554. https://doi.org/10.1177/1523422308319536

Atta-Owusu, K., Fitjar, R. D., & Rodríguez-Pose, A. (2021). What drives university-industry collaboration? Research excellence or firm collaboration strategy? Technological Forecasting and Social Change, 173, 121084. https://doi.org/10.1016/j.techfore.2021.121084

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology, 51(6), 1173–1182. https://doi.org/10.1037/0022-3514.51.6.1173

Basias, N., & Pollalis, Y. (2019). Quantitative and Qualitative Research in Business & Technology: Justifying a Suitable Research Methodology. Review of Integrative Business and Economics Research, 7(1), 91–115. http://buscompress.com/uploads/3/4/9/8/34980536/riber_7-s1_sp_h17-083_91-105.pdf

Basit, S. A. (2021). The Effect of External Knowledge Sources on Organizational Innovation in Small and Medium Enterprises in Germany. Business Systems Research Journal, 12(1), 60–79. https://doi.org/10.2478/bsrj-2021-0005

Bigliardi, B., Ferraro, G., Filippelli, S. & Galati, F. (2020). The past, present and future of Open Innovation. European Journal of Innovation Management, 24(4), 1130–1161. https://doi.org/10.1108/ejim-10-2019-0296

Binz, C., & Truffer, B. (2017). Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. Research Policy, 46(7), 1284–1298. https://doi.org/10.1016/j.respol.2017.05.012

Blok, V., & Lemmens, P. (2015). The Emerging Concept of Responsible Innovation. Three Reasons Why It Is Questionable and Calls for a Radical Transformation of the Concept of Innovation. Responsible Innovation 2, 19–35. https://doi.org/10.1007/978-3-319-17308-5_2

Bogers, M., Chesbrough, H. & Moedas, C. (2018). Open Innovation: Research, Practices, and Policies. California Management Review, 60(2), 5–16. https://doi.org/10.1177/0008125617745086

Bronzini, R., & Piselli, P. (2016). The impact of R&D subsidies on firm innovation. Research Policy, 45(2), 442–457. https://doi.org/10.1016/j.respol.2015.10.008

Buenechea-Elberdin, M., Sáenz, J., & Kianto, A. (2017). Exploring the role of human capital, renewal capital and entrepreneurial capital in innovation performance in high-tech and low-tech firms. Knowledge Management Research & Practice, 15(3), 369–379. https://doi.org/10.1057/s41275-017-0069-3

Cáceres, R., Guzmán, J., & Rekowski, M. (2011). Firms as source of variety in innovation: influence of size and sector. International Entrepreneurship and Management Journal, 7(3), 357–372. https://doi.org/10.1007/s11365-011-0198-8

Cai, Y., & Etzkowitz, H. (2020). Theorizing the Triple Helix model: Past, present, and future. Triple Helix Journal, 1–38. https://doi.org/10.1163/21971927-bja10003

Cai, Y., & Lattu, A. (2021). Triple Helix or Quadruple Helix: Which Model of Innovation to Choose for Empirical Studies? Minerva, 60(2), 257–280. https://doi.org/10.1007/s11024-021-09453-6

Cambra-Fierro, J., Melero-Polo, I., & Sese, F. J. (2018). Customer value co-creation over the relationship life cycle. Journal of Service Theory and Practice, 28(3), 336–355. https://doi.org/10.1108/jstp-01-2017-0009

Carayannis, E. G., & Campbell, D. F. (2009). 'Mode 3' and 'Quadruple Helix': toward a 21st century fractal innovation ecosystem. International Journal of Technology Management, 46(3/4), 201. https://doi.org/10.1504/ijtm.2009.023374

Carayannis, E. G., & Campbell, D. F. (2010). Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation and the Environment Relate To Each Other? International Journal of Social Ecology and Sustainable Development, 1(1), 41–69. https://doi.org/10.4018/jsesd.2010010105

Carayannis, E. G., & Campbell, D. F. (2012). Mode 3 Knowledge Production in Quadruple Helix Innovation Systems (Vol. 7). Springer Publishing.

Carayannis, E. G., & Campbell, D. F. (2014). Developed democracies versus emerging autocracies: arts, democracy, and innovation in Quadruple Helix innovation systems. Journal of Innovation and Entrepreneurship, 3(1). https://doi.org/10.1186/s13731-014-0012-2

Carayannis, E. G., & Campbell, D. F. (2021). Democracy of Climate and Climate for Democracy: the Evolution of Quadruple and Quintuple Helix Innovation Systems. Journal of the Knowledge Economy, 12(4), 2050–2082. https://doi.org/10.1007/s13132-021-00778-x

Carayannis, E. G., & Morawska-Jancelewicz, J. (2022). The Futures of Europe: Society 5.0 and Industry 5.0 as Driving Forces of Future Universities. Journal of the Knowledge Economy. https://doi.org/10.1007/s13132-021-00854-2

Carayannis, E. G., Dezi, L., Gregori, G., & Calo, E. (2021). Smart Environments and Techno-centric and Human-Centric Innovations for Industry and Society 5.0: A Quintuple Helix Innovation System View Towards Smart, Sustainable, and Inclusive Solutions. Journal of the Knowledge Economy. https://doi.org/10.1007/s13132-021-00763-4

Carayannis, E. G., Grigoroudis, E., Campbell, D. F., Meissner, D., & Stamati, D. (2017). The ecosystem as helix: an exploratory theory-building study of regional co-opetitive entrepreneurial ecosystems as Quadruple/Quintuple Helix Innovation Models. *R&D Management*, *48*(1), 148–162. https://doi.org/10.1111/radm.12300

Carayannis, E. G., Grigoroudis, E., Campbell, D. F., Meissner, D., & Stamati, D. (2018). 'Mode 3' universities and academic firms: thinking beyond the box trans-disciplinarity and nonlinear innovation dynamics within coopetitive entrepreneurial ecosystems. *International Journal of Technology Management*, *77*(1/2/3), 145. https://doi.org/10.1504/ijtm.2018.091714

Cavallini, S., Soldi, R., Friedl, J., & Volpe, M. (2016). *Using the quadruple helix approach to accelerate the transfer of research and innovation results to regional growth*. Committee of the Regions. Retrieved from https://op.europa.eu/s/wsBm

Cepeda, J. & Arias-Pérez, J. (2019). Information technology capabilities and organizational agility. Multinational Business Review, 27(2), 198–216. https://doi.org/10.1108/mbr-11-2017-0088

Chatterji, A. K., & Fabrizio, K. R. (2013). Using users: When does external knowledge enhance corporate product innovation? Strategic Management Journal, 35(10), 1427–1445. https://doi.org/10.1002/smj.2168

Chen, J., Han, L., & Qu, G. (2020). Citizen Innovation: Exploring the Responsibility Governance and Cooperative Mode of a "Post-Schumpeter" Paradigm. *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(4), 172. https://doi.org/10.3390/joitmc6040172

Chesbrough, H., & Bogers, M. (2014). Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation. In New Frontiers in Open Innovation (pp. 3–16). Oxford University Press.

Chesbrough, H. (2019). Open Innovation Results: Going Beyond the Hype and Getting Down to Business (1st ed.). Oxford University Press.

Chesbrough, H. W. (2003). Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business Review Press.

Chesbrough, H., Vanhaverbeke, W., & West, J. (2014). New Frontiers in Open Innovation. Oxford University Press.

Colapinto, C., & Porlezza, C. (2011). Innovation in Creative Industries: from the Quadruple Helix Model to the Systems Theory. Journal of the Knowledge Economy, 3(4), 343–353. https://doi.org/10.1007/s13132-011-0051-x

Compagnucci, L., Spigarelli, F., Coelho, J., & Duarte, C. (2021). Living Labs and user engagement for innovation and sustainability. Journal of Cleaner Production, 289, 125721. https://doi.org/10.1016/j.jclepro.2020.125721

Costa, J., & Fonseca, J. P. (2022). The Impact of Corporate Social Responsibility and Innovative Strategies on Financial Performance. Risks, 10(5), 103. https://doi.org/10.3390/risks10050103

Costa, J., & Matias, J. C. (2020). Open Innovation 4.0 as an Enhancer of Sustainable Innovation Ecosystems. Sustainability, 12(19), 8112. https://doi.org/10.3390/su12198112

Costa, J., Botelho, A., & Matias, J. (2018). Hindering Factors to Innovation: A Panel Data Analysis. Entrepreneurship and the Industry Life Cycle, 269–298. https://doi.org/10.1007/978-3-319-89336-5_12

Costa, J., Freire, P., & Reis, J. (2021). Open Innovation and User-Community as Enhancers of Sustainable Innovation Ecosystems. Springer Proceedings in Mathematics & Statistics, 65–77. https://doi.org/10.1007/978-3-030-78570-3_5

Crescenzi, R., & Gagliardi, L. (2018). The innovative performance of firms in heterogeneous environments: The interplay between external knowledge and internal absorptive capacities. Research Policy, 47(4), 782–795. https://doi.org/10.1016/j.respol.2018.02.006

Dahlin, P., Moilanen, M., Østbye, S. E., & Pesämaa, O. (2019). Absorptive capacity, co-creation, and innovation performance. Baltic Journal of Management, 15(1), 81–98. https://doi.org/10.1108/bjm-05-2019-0161

Damioli, G., Ghisetti, C., Vertesy, D., & Vezzulli, A. (2019). Open for growth? Evidence on EU countries and sectors. Economics of Innovation and New Technology, 30(2), 197–219. https://doi.org/10.1080/10438599.2019.1688459

D'Este, P., Rentocchini, F., & Vega-Jurado, J. (2014). The Role of Human Capital in Lowering the Barriers to Engaging in Innovation: Evidence from the Spanish Innovation Survey. Industry and Innovation, 21(1), 1–19. https://doi.org/10.1080/13662716.2014.879252

Direção-Geral de Estatísticas da Educação e Ciência. (2020). Inquérito Comunitário à Inovação: 2016–2018. Instituto Nacional de Estatística. Retrieved 25 June 2022, from https://www.ine.pt/xurl/pub/452685463

Doran, J., & Jordan, D. (2016). Cross-sectoral differences in the drivers of innovation. Journal of Economic Studies, 43(5), 719–748. https://doi.org/10.1108/jes-10-2014-0171

Durán-Romero, G., López, A. M., Beliaeva, T., Ferasso, M., Garonne, C., & Jones, P. (2020). Bridging the gap between circular economy and climate change mitigation policies through eco-innovations and Quintuple Helix Model. Technological Forecasting and Social Change, 160, 120246. https://doi.org/10.1016/j.techfore.2020.120246

Durugbo, C., & Pawar, K. (2014). A unified model of the co-creation process. Expert Systems with Applications, 41(9), 4373–4387. https://doi.org/10.1016/j.eswa.2014.01.007

Ek, P., & Sörhammar, D. (2022). Effects Of User Community Sensing Capability In Digital Product Innovation: Evidence From The Video Game Industry. International Journal of Innovation Management. https://doi.org/10.1142/s1363919622500074

Escobar, O., Schiavone, F., Khvatova, T., & Maalaoui, A. (2021). Lead user innovation and entrepreneurship: Analyzing the current state of research. *Journal of Small Business Management*, 1–18. https://doi.org/10.1080/00472778.2021.1955126

Etzkowitz, H. (1989). Entrepreneurial Science in the Academy: A Case of the Transformation of Norms. Social Problems, 36(1), 14–29. https://doi.org/10.2307/800547

Etzkowitz, H. (2014). Making a humanities town: knowledge-infused clusters, civic entrepreneurship and civil society in local innovation systems. Triple Helix, 2(1). https://doi.org/10.1186/s40604-014-0012-z

European Commission. (2011). Corporate Social Responsibility: a new definition, a new agenda for action. Author. Retrieved from https://ec.europa.eu/commission/presscorner/detail/htm/MEMO_11_730

European Commission. (2020). European Innovation Scoreboard. European Commission. Retrieved from https://ec.europa.eu/docsroom/documents/42981

Faems, D. (2020). Moving forward quantitative research on innovation management: a call for an inductive turn on using and presenting quantitative research. R&D Management, 50(3), 352–363. https://doi.org/10.1111/radm.12406

Fagerberg, J. (2018). Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy. *Research Policy*, *47*(9), 1568–1576. https://doi.org/10.1016/j.respol.2018.08.012

Farace, S., & Mazzotta, F. (2015). The effect of human capital and networks on knowledge and innovation in SMEs. Journal of Innovation Economics & Management, n°16(1), 39–71. https://doi.org/10.3917/jie.016.0039

Füller, J., Bartl, M., Ernst, H., & Mühlbacher, H. (2006). Community based innovation: How to integrate members of virtual communities into new product development. Electronic Commerce Research, 6(1), 57–73. https://doi.org/10.1007/s10660-006-5988-7

Füller, J., Mühlbacher, H., Matzler, K., & Jawecki, G. (2009). Consumer Empowerment Through Internet-Based Co-creation. Journal of Management Information Systems, 26(3), 71–102. https://doi.org/10.2753/mis0742-1222260303

Gallego-Álvarez, I., Manuel Prado-Lorenzo, J., & García-Sánchez, I. (2011). Corporate social responsibility and innovation: a resource-based theory. Management Decision, 49(10), 1709–1727. https://doi.org/10.1108/00251741111183843

Gambardella, A., Raasch, C., & von Hippel, E. (2017). The User Innovation Paradigm: Impacts on Markets and Welfare. Management Science, 63(5), 1450–1468. https://doi.org/10.1287/mnsc.2015.2393

Garcia, M., Martinez, M., & Martinez, R. (2014). The Effects of the Value Co-Creation Process on the Consumer and the Company. Expert Journal of Marketing, 68–81. Retrieved from https://marketing.expertjournals.com/23446773-208/

Geng, D., & Kali, R. (2021). Trade and innovation: Unraveling a complex nexus. International Journal of Innovation Studies, 5(1), 23–34. https://doi.org/10.1016/j.ijis.2021.01.001

Genus, A., & Stirling, A. (2018). Collingridge and the dilemma of control: Towards responsible and accountable innovation. Research Policy, 47(1), 61–69. https://doi.org/10.1016/j.respol.2017.09.012

González-Martinez, P., García-Pérez-De-Lema, D., Castillo-Vergara, M., & Bent Hansen, P. (2021). Systematic Review of The Literature on The Concept of Civil Society in The Quadruple Helix Framework. *Journal of Technology Management & Innovation*, *16*(4), 85–95. https://doi.org/10.4067/s0718-27242021000400085

Grabher, G., & Ibert, O. (2018). Schumpeterian Customers? How Active Users Co-create Innovations. Oxford Handbooks Online. https://doi.org/10.1093/oxfordhb/9780198755609.013.36

Grabowska, S., Saniuk, S., & Gajdzik, B. (2022). Industry 5.0: improving humanization and sustainability of Industry 4.0. Scientometrics, 127(6), 3117–3144. https://doi.org/10.1007/s11192-022-04370-1

Greco, M., Grimaldi, M., & Cricelli, L. (2015). Open innovation actions and innovation performance. European Journal of Innovation Management, 18(2), 150–171. https://doi.org/10.1108/ejim-07-2013-0074

Guo, W., Zheng, Q., An, W., & Peng, W. (2017). User roles and contributions during the new product development process in collaborative innovation communities. Applied Ergonomics, 63, 106–114. https://doi.org/10.1016/j.apergo.2017.04.013

Gur, U. (2020). Transformative University in Quadruple Helix Sustainability Governance. The Handbook of Open Smart Cities: Planning and Managing Open Innovative Ecosystems, 41–55. https://doi.org/10.1108/978-1-78973-409-620201004

Gurzawska, A. (2021). Responsible Innovation in Business: Perceptions, Evaluation Practices and Lessons Learnt. Sustainability, 13(4), 1826. https://doi.org/10.3390/su13041826

Guzzini, E., & Iacobucci, D. (2017). Project failures and innovation performance in university–firm collaborations. The Journal of Technology Transfer, 42(4), 865–883. https://doi.org/10.1007/s10961-016-9554-8

Harhoff, D., Henkel, J., & von Hippel, E. (2003). Profiting from voluntary information spillovers: how users benefit by freely revealing their innovations. Research Policy, 32(10), 1753–1769. https://doi.org/10.1016/s0048-7333(03)00061-1

Hartley, S., McLeod, C., Clifford, M., Jewitt, S., & Ray, C. (2019). A retrospective analysis of responsible innovation for low-technology innovation in the Global South. Journal of Responsible Innovation, 6(2), 143–162. https://doi.org/10.1080/23299460.2019.1575682

Hasche, N., Höglund, L., & Linton, G. (2019). Quadruple helix as a network of relationships: creating value within a Swedish regional innovation system. Journal of Small Business & Entrepreneurship, 32(6), 523–544. https://doi.org/10.1080/08276331.2019.1643134

Hashi, I., & Stojčić, N. (2013). The impact of innovation activities on firm performance using a multi-stage model: Evidence from the Community Innovation Survey 4. Research Policy, 42(2), 353–366. https://doi.org/10.1016/j.respol.2012.09.011

Hayek, F. A. (1945). The Use of Knowledge in Society. Readings in the Economics of the Division of Labor, 270–284. https://doi.org/10.1142/9789812701275_0025

Hofstetter, R., Aryobsei, S., & Herrmann, A. (2017). Should You Really Produce What Consumers Like Online? Empirical Evidence for Reciprocal Voting in Open Innovation Contests. Journal of Product Innovation Management, 35(2), 209–229. https://doi.org/10.1111/jpim.12382

Javaid, M., & Haleem, A. (2020). Critical Components of Industry 5.0 Towards a Successful Adoption in the Field of Manufacturing. Journal of Industrial Integration and Management, 05(03), 327–348. https://doi.org/10.1142/s2424862220500141

Jeppesen, L. B., & Frederiksen, L. (2006). Why Do Users Contribute to Firm-Hosted User Communities? The Case of Computer-Controlled Music Instruments. Organization Science, 17(1), 45–63. https://doi.org/10.1287/orsc.1050.0156

Kampik, F., & Dachs, B. (2011). The innovative performance of German multinationals abroad: evidence from the European community innovation survey. Industrial and Corporate Change, 20(2), 661–681. https://doi.org/10.1093/icc/dtr008

Kobarg, S., Stumpf-Wollersheim, J., & Welpe, I. M. (2017). University-industry collaborations and product innovation performance: the moderating effects of absorptive capacity and innovation competencies. The Journal of Technology Transfer, 43(6), 1696–1724. https://doi.org/10.1007/s10961-017-9583-y

Kolehmainen, J., Irvine, J., Stewart, L., Karacsonyi, Z., Szabó, T., Alarinta, J., & Norberg, A. (2015). Quadruple Helix, Innovation and the Knowledge-Based Development: Lessons from Remote, Rural and Less-Favoured Regions. Journal of the Knowledge Economy, 7(1), 23–42. https://doi.org/10.1007/s13132-015-0289-9

Księżak, P. (2017). The Benefits from CSR for a Company and Society. Journal of Corporate Responsibility and Leadership, 3(4), 53. https://doi.org/10.12775/jcrl.2016.023

Lee, C. C., Lee, L. C., & Kao, R. H. (2022). How do Enterprises promote innovation performance? A study on the relationship between online communities and innovation performance-exploring the mediating effect of tacit knowledge. Current Psychology. https://doi.org/10.1007/s12144-022-02890-w

Leydesdorff, L. (2011). The Triple Helix, Quadruple Helix, . . ., and an N-Tuple of Helices: Explanatory Models for Analyzing the Knowledge-Based Economy? Journal of the Knowledge Economy, 3(1), 25–35. https://doi.org/10.1007/s13132-011-0049-4

Liakos, N., Kumar, V., Pongsakornrungsilp, S., Garza-Reyes, J. A., Gupta, B., & Pongsakornrungsilp, P. (2019). Understanding circular economy awareness and practices in manufacturing firms. Journal of Enterprise Information Management, 32(4), 563–584.

Liu, Q., Zhao, X., & Sun, B. (2018). Value co-creation mechanisms of enterprises and users under crowdsource-based open innovation. International Journal of Crowd Science, 2(1), 2–17. https://doi.org/10.1108/ijcs-01-2018-0001

Mačaitytė, I., & Virbašiūtė, G. (2018). Volkswagen Emission Scandal and Corporate Social Responsibility – A Case Study. Business Ethics and Leadership, 2(1), 6–13. https://doi.org/10.21272/bel.2(1).6-13.2018

Maddikunta, P. K. R., Pham, Q. V., B, P., Deepa, N., Dev, K., Gadekallu, T. R., Ruby, R., & Liyanage, M. (2022). Industry 5.0: A survey on enabling technologies and potential applications. Journal of Industrial Information Integration, 26, 100257. https://doi.org/10.1016/j.jii.2021.100257

Magnusson, P. R. (2009). Exploring the Contributions of Involving Ordinary Users in Ideation of Technology-Based Services. Journal of Product Innovation Management, 26(5), 578–593. https://doi.org/10.1111/j.1540-5885.2009.00684.x

Mahr, D., & Lievens, A. (2012). Virtual lead user communities: Drivers of knowledge creation for innovation. Research Policy, 41(1), 167–177. https://doi.org/10.1016/j.respol.2011.08.006

Markovic, S., & Bagherzadeh, M. (2018). How does breadth of external stakeholder co-creation influence innovation performance? Analyzing the mediating roles of knowledge sharing and product innovation. Journal of Business Research, 88, 173–186. https://doi.org/10.1016/j.jbusres.2018.03.028

McGahan, A. M., Bogers, M. L. A. M., Chesbrough, H., & Holgersson, M. (2020). Tackling Societal Challenges with Open Innovation. California Management Review, 63(2), 49–61. https://doi.org/10.1177/0008125620973713

Meelen, T., Truffer, B., & Schwanen, T. (2019). Virtual user communities contributing to upscaling innovations in transitions: The case of electric vehicles. Environmental Innovation and Societal Transitions, 31, 96–109. https://doi.org/10.1016/j.eist.2019.01.002

Messeni Petruzzelli, A., Ardito, L., & Savino, T. (2018). Maturity of knowledge inputs and innovation value: The moderating effect of firm age and size. Journal of Business Research, 86, 190–201. https://doi.org/10.1016/j.jbusres.2018.02.009

Mineiro, A. A. D. C., Assis De Souza, T., & Carvalho De Castro, C. (2021). The quadruple and quintuple helix in innovation environments (incubators and science and technology parks). Innovation & Management Review, 18(3), 292–307. https://doi.org/10.1108/inmr-08-2019-0098

Mohamed, M. (2018). Challenges and Benefits of Industry 4.0: an overview. International Journal of Supply and Operations Management, 5(3), 256–265. https://doi.org/10.22034/2018.3.7

Nahavandi, S. (2019). Industry 5.0—A Human-Centric Solution. Sustainability, 11(16), 4371. https://doi.org/10.3390/su11164371

Odei, S. A., Stejskal, J., & Prokop, V. (2021). Understanding territorial innovations in European regions: Insights from radical and incremental innovative firms. Regional Science Policy & Practice, 13(5), 1638–1660. https://doi.org/10.1111/rsp3.12446

Oertzen, A. S., Odekerken-Schröder, G., & Mager, B. (2020). Driving users' behaviours and engagement in co-creating services. Journal of Services Marketing, 34(4), 549–573. https://doi.org/10.1108/jsm-06-2019-0244

OECD/Eurostat (2005), Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition, The Measurement of Scientific and Technological Activities, OECD Publishing, Paris, https://doi.org/10.1787/9789264013100-en.

OECD (2019). "High-skilled employment, co-operation with HEIs and innovation in the business sector", in OECD Review of Higher Education, Research and Innovation: Portugal, OECD Publishing. https://doi.org/10.1787/805f7753-en.

Pan, H. (2020). Online Community Value Co-creation. Online Information Review, 44(3), 645–669. https://doi.org/10.1108/oir-09-2018-0276

Pansera, M., & Owen, R. (2018). Framing inclusive innovation within the discourse of development: Insights from case studies in India. Research Policy, 47(1), 23–34. https://doi.org/10.1016/j.respol.2017.09.007

Papa, A., Dezi, L., Gregori, G. L., Mueller, J., & Miglietta, N. (2018). Improving innovation performance through knowledge acquisition: the moderating role of employee retention and human resource management practices. Journal of Knowledge Management, 24(3), 589–605. https://doi.org/10.1108/jkm-09-2017-0391

Prause, G., & Thurner, T. (2014). User Communities — Drivers for Open Innovation. Foresight-Russia, 8(1), 24–32. https://doi.org/10.17323/1995-459x.2014.1.24.32

Ramaswamy, V., & Ozcan, K. (2014). The Co-Creation Paradigm. Amsterdam University Press.

Rayna, T., & Striukova, L. (2015). Open innovation 2.0: is co-creation the ultimate challenge? International Journal of Technology Management, 69(1), 38. https://doi.org/10.1504/ijtm.2015.071030

Roman, M., & Fellnhofer, K. (2022). Facilitating the participation of civil society in regional planning: Implementing quadruple helix model in Finnish regions. Land Use Policy, 112, 105864. https://doi.org/10.1016/j.landusepol.2021.105864

Roman, M., & Nyberg, T. (2017). Openness and Continuous Collaboration as the Foundation for Entrepreneurial Discovery Process in Finnish Regions. Management Dynamics in the Knowledge Economy, 5(4), 517–531. https://doi.org/10.25019/mdke/5.4.04

Roman, M., Varga, H., Cvijanovic, V., & Reid, A. (2020). Quadruple Helix Models for Sustainable Regional Innovation: Engaging and Facilitating Civil Society Participation. *Economies*, *8*(2), 48. https://doi.org/10.3390/economies8020048

Romero, D., & Molina, A. (2011). Collaborative networked organisations and customer communities: value co-creation and co-innovation in the networking era. Production Planning & Control, 22(5–6), 447–472. https://doi.org/10.1080/09537287.2010.536619

Samad, S. (2020). Achieving innovative firm performance through human capital and the effect of social capital. Management & Marketing. Challenges for the Knowledge Society, 15(2), 326–344. https://doi.org/10.2478/mmcks-2020-0019

Schlaile, M. P., Mueller, M., Schramm, M., & Pyka, A. (2017). Evolutionary Economics, Responsible Innovation and Demand: Making a Case for the Role of Consumers. Philosophy of Management, 17(1), 7–39. https://doi.org/10.1007/s40926-017-0054-1

Schütz, F., Heidingsfelder, M. L., & Schraudner, M. (2019). Co-shaping the Future in Quadruple Helix Innovation Systems: Uncovering Public Preferences toward Participatory Research and Innovation. She Ji: The Journal of Design, Economics, and Innovation, 5(2), 128–146. https://doi.org/10.1016/j.sheji.2019.04.002

Shah, S. K., & Nagle, F. (2019). Why Do User Communities Matter for Strategy? Strategic Management Review, 1(2), 305–353. https://doi.org/10.1561/111.00000012

Shu, P., & Steinwender, C. (2019). The Impact of Trade Liberalization on Firm Productivity and Innovation. Innovation Policy and the Economy, 19, 39–68. https://doi.org/10.1086/699932

Sieber, S., Valor, J., & Miralles, F. (2005). CIO Herds and User Gangs in the Adoption of Open Source Software. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.875592

Silva, L. M. D., Bitencourt, C. C., Faccin, K., & Iakovleva, T. (2019). The Role of Stakeholders in the Context of Responsible Innovation: A Meta-Synthesis. Sustainability, 11(6), 1766. https://doi.org/10.3390/su11061766

Sindhwani, R., Afridi, S., Kumar, A., Banaitis, A., Luthra, S., & Singh, P. L. (2022). Can industry 5.0 revolutionize the wave of resilience and social value creation? A multi-criteria framework to analyze enablers. Technology in Society, 68, 101887. https://doi.org/10.1016/j.techsoc.2022.101887

Sprinkle, G. B., & Maines, L. A. (2010). The benefits and costs of corporate social responsibility. Business Horizons, 53(5), 445–453. https://doi.org/10.1016/j.bushor.2010.05.006

Stejskal, J., Hajek, P., & Prokop, V. (2018). Collaboration And Innovation Models In Information And Communication Creative Industries – The Case Of Germany. Journal of Information and Communication Technology, 17(2). https://doi.org/10.32890/jict2018.17.2.2

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. Research Policy, 42(9), 1568–1580. https://doi.org/10.1016/j.respol.2013.05.008

Surowiecki, J. (2004). The Wisdom of Crowds. Doubleday.

Tavassoli, S., & Karlsson, C. (2015). Persistence of various types of innovation analyzed and explained. Research Policy, 44(10), 1887–1901. https://doi.org/10.1016/j.respol.2015.06.001

Vega-Jurado, J., Gutiérrez-Gracia, A., Fernández-de-Lucio, I., & Manjarrés-Henríquez, L. (2008). The effect of external and internal factors on firms' product innovation. Research Policy, 37(4), 616–632. https://doi.org/10.1016/j.respol.2008.01.001

Venesz, B., Dőry, T., & Raišienė, A. G. (2022). Characteristics of Lead Users in Different Stages of the New Product Development Process: A Systematic Review in the Context of Open Innovation. Journal of Open Innovation: Technology, Market, and Complexity, 8(1), 24. https://doi.org/10.3390/joitmc8010024

Verleye, K. (2015). The co-creation experience from the customer perspective: its measurement and determinants. Journal of Service Management, 26(2), 321–342. https://doi.org/10.1108/josm-09-2014-0254

Voegtlin, C., & Scherer, A. G. (2015). Responsible Innovation and the Innovation of Responsibility: Governing Sustainable Development in a Globalized World. Journal of Business Ethics, 143(2), 227–243. https://doi.org/10.1007/s10551-015-2769-z

von Hippel, E. (2005). Democratizing Innovation. The MIT Press.

von Hippel, E. (2016). Free Innovation. The MIT Press.

von Hippel, E. (2017). Free Innovation by Consumers—How Producers Can Benefit. Research-Technology Management, 60(1), 39–42. https://doi.org/10.1080/08956308.2017.1255055

Vrande, V. V. D., Vanhaverbeke, W., & Gassmann, O. (2010). Broadening the scope of open innovation: past research, current state and future directions. International Journal of Technology Management, 52(3/4), 221. https://doi.org/10.1504/ijtm.2010.035974

Wang, C. H. (2019). How organizational green culture influences green performance and competitive advantage. Journal of Manufacturing Technology Management, 30(4), 666–683. https://doi.org/10.1108/jmtm-09-2018-0314

Wang, Y., Li, C., Zhang, D., Wu, J., & Liu, Y. (2020). A deeper investigation of different types of core users and their contributions for sustainable innovation in a company-hosted online co-creation community. Journal of Cleaner Production, 256, 120397. https://doi.org/10.1016/j.jclepro.2020.120397

Wasono, L. W. W., Mihardjo, S., & Alamsyah, F. (2019). Boosting the Firm Transformation in Industry 5.0: Experience-Agility Innovation Model. International Journal of Recent Technology and Engineering, 8(2S9), 735–742. https://doi.org/10.35940/ijrte.b1154.0982s919

West, J., & Bogers, M. (2013). Leveraging External Sources of Innovation: A Review of Research on Open Innovation. Journal of Product Innovation Management, 31(4), 814–831. https://doi.org/10.1111/jpim.12125

West, J., Salter, A., Vanhaverbeke, W., & Chesbrough, H. (2014). Open innovation: The next decade. Research Policy, 43(5), 805–811. https://doi.org/10.1016/j.respol.2014.03.001

Xu, X., Lu, Y., Vogel-Heuser, B., & Wang, L. (2021). Industry 4.0 and Industry 5.0—Inception, conception and perception. Journal of Manufacturing Systems, 61, 530–535. https://doi.org/10.1016/j.jmsy.2021.10.006

Yang, Q. & Li, C. (2019). User Roles and Contributions in User Innovation Community. American Journal of Industrial and Business Management, 9, 1318-1331. https://doi.org/10.4236/ajibm.2019.96087

Yun, J. & Liu, Z. (2019). Micro- and Macro-Dynamics of Open Innovation with a Quadruple-Helix Model. Sustainability, 11(12), 3301. https://doi.org/10.3390/su11123301

Zare, S., Bettiga, D., & Lamberti, L. (2018). Does one design fit them all? Study of drivers of co-creation interest along different consumer segments. Journal of Strategic Marketing, 27(7), 630–650. https://doi.org/10.1080/0965254x.2018.1464051

Zhang, T., Lu, C., Torres, E., & Chen, P. J. (2018). Engaging customers in value co-creation or co-destruction online. Journal of Services Marketing, 32(1), 57–69. https://doi.org/10.1108/jsm-01-2017-0027

Zhang, T., Lu, C., Torres, E., & Cobanoglu, C. (2020). Value co-creation and technological progression: a critical review. European Business Review, 32(4), 687–707. https://doi.org/10.1108/ebr-08-2019-0149

Zhao, S., Sun, Y., & Xu, X. (2015). Research on open innovation performance: a review. *Information Technology and Management*, *17*(3), 279–287. https://doi.org/10.1007/s10799-015-0231-7

Appendix

Annex A. Model Log-Likelihood

	Model Log-Likelihood	Change in -2 Log-Likelihood	df	Sig. of the Change
INTER_COMM(9)	-6871,477	586,402	1	<0,001
INTER_IND(6)	-6738,769	320,988	1	<0,001
INTER_ACAD(7)	-6580,632	4,713	1	0,030
INTER_GOV(8)	-6634,096	111,642	1	<0,001
H_CAP(10)	-6647,546	138,541	1	<0,001
EXP(11)	-6655,091	153,631	1	<0,001
SIZE(12)	-6613,682	70,812	1	<0,001
TECH(13)	-6579,075	1,599	1	0,206