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Open Innovation in Micro, Small and Medium-Sized Enterprises

Edited by
João Leitão and Léo-Paul Dana

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About the Editors

João Leitão

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Léo-Paul Dana

Since the 1980s, Leo Dana has been researching for and with Indigenous peoples—those whose ancestors were living in an area prior to colonisation or within a nation-state prior to its formation. He defined Indigenous entrepreneurship as self-employment based on Indigenous knowledge and worked on a team to develop a relevant model.

The focus of Dr. Dana's Ph.D. thesis was First Nations and Inuit. He subsequently embarked on detailed studies of Alaska Native people, Berbers in Morocco, Guarani people in Paraguay, the Mapuche economy in Chile, and reindeer herding among the Sami in Fennoscandia.

There is rich heterogeneity among Indigenous peoples and some of their cultural values are often incompatible with the basic assumptions of mainstream theories of entrepreneurship. This makes research very rewarding, especially since Indigenous entrepreneurship often has non-economic explanatory variables. Some Indigenous economies display elements of egalitarianism, sharing and communal activity, contrasting with capitalism as it is known in mainstream society. Indigenous entrepreneurship is usually environmentally sustainable, which often allows Indigenous people to rely on immediately available resources. A function of these resources, work in Indigenous communities is often irregular. Social organization among Indigenous peoples is often based on kinship ties, not necessarily created in response to market needs. Much Indigenous entrepreneurial activity involves internal economic activity with no transaction, while transactions often take place in the bazaar and the informal sector, where enterprises often have limited inventory. Perhaps his most important finding is that the causal variable behind entrepreneurship is not simply an opportunity, but rather one's cultural perception of opportunity.

Preface to "Open Innovation in Micro, Small and Medium-Sized Enterprises"

Research defines coopetition as a mix of cooperation and competition among firms oriented towards producing innovation, and generating net value added or economic benefit. The importance of studying the determinants of firms' innovative behaviour, based on those coopetition relationships, has warranted increasing attention from scholars. However, the role played by micro-, small-, and medium-sized enterprises in this process have been neglected, even as research on economic geography, clusters, entrepreneurship, and innovation has become pre-eminent. This represents an opportunity for scholars, policymakers, entrepreneurs, and practitioners to discuss the importance of micro-, small-, and medium-sized enterprises in determining the innovative behaviour of government, industry, higher education institutions (HEIs), and citizens in environments that mix competition and cooperation.

Despite the importance of the institutional and network approaches explored in the literature, much remains unknown regarding the role played by the referred different types of enterprises in determining innovative and economic performance. Another gap found in the literature is concerning entrepreneurial and open innovative ecosystems. There is increasing literature suggesting reasons behind ecosystems emergence, but it fails to examine, in detail, the exact mechanisms behind it, namely, the role played by endogenous production factors (for example, human capital, social or relational capital, organizational capital, and knowledge), using an organizational economics approach. This gap may be addressed by linking, for example, coopetition, innovative behaviour, clusters, or industrial districts. If agglomeration improves the quality of the match between government, firms, HEIs, and citizens, then clusters will ensure enduring productivity and sustainable competitive advantages.

The collection of 13 contributions is quite impressive, in the sense that congregates in the same volume several benchmarks of international practices of open innovation, revealing the importance of micro-, small-, and medium-sized firms for reinforcing the evolutionary innovation pathway undercut with established firms, public institutions, and civil society.

Research avenues are provided to scholars, policymakers and practitioners that are interested in moving forward with the open innovation paradigm, recovering the importance of the open debate devoted to the innovative nature of new entrepreneurial units, which are responsible for creating qualified work, innovations, and new specializations.

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João Leitão and Léo-Paul Dana
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Article

Inbound and Outbound Practices of Open Innovation and Eco-Innovation: Contrasting Bioeconomy and Non-Bioeconomy Firms

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Abstract: Generating innovation with environmental impact is crucial for firms to achieve sustainable eco-innovative performance. In the reference literature on open innovation, gaps still persist at the level of scarce and limited knowledge on the use of knowledge sources and flows, for the purpose of strengthening the eco-innovative performance of the bioeconomy sector. To address these caveats, this study analyses the effects of open innovation on eco-innovation, based on inbound and outbound support practices. Specifically, it aims to analyse the effects of these practices on the eco-innovative performance of bioeconomy and non-bioeconomy firms, using secondary data gathered from the Community Innovation Survey—CIS 2010 for a sample of moderately innovative countries, namely Slovakia, Spain, Hungary, Italy, Portugal and the Czech Republic. The conceptual model proposed is tested using multivariate tobit regression models, in order to ensure the accuracy and reliability required to validate empirical tests. Overall, the empirical evidence allows the conclusion that inbound and outbound practices and public policies have a positive and significant influence on the eco-innovative performance of the firms studied. The contribution provided is two-fold: (i) in theoretical terms, an operational model of open innovation inbound and outbound practices is extended, crossing financial flows and innovation directions; and (ii) in empirical terms, new light is shed on the still limited knowledge about the positive and significant effects of open innovation outbound practices on the eco-innovative performance of companies belonging to a global strategic sector—that is, the bioeconomy sector, which has renewed strategic importance in the face of global climate change.

Keywords: bioeconomy; eco-innovation; inbound; open innovation; outbound

1. Introduction

Creating innovation with a sustainable environmental impact is of great importance for firms, which use open eco-innovation to raise performance and create economic and environmental value [1–4]. Every innovation strategy provides a clear direction for addressing strategic issues, the selection of the market where the company wants to enter and abilities to be developed [5]. Although in the past firms adopted mainly internal research and development activities to create technology and products, this process being known as the closed innovation model [6], in recent decades, the innovation

framework has changed considerably, with many companies adopting an open innovation model, in which they use internal and external paths to develop and exploit new technology and products [6].

Open innovation was stimulated predominately by Chesbrough [6] and since then it has been subject to wide debate and extensive study in the literature of reference on innovation, with a special focus on innovation management [7]. It corresponds to a model of organisation that includes the commercialization of firms' internal and external ideas, following internal and external paths towards the market. This implies the search for knowledge flows from and to the firm environment, taking advantage of potential sources of ideas in third parties [8–10]. This process resorts to complex networks of partners and external stakeholders, who cooperate through open innovation systems with inbound and outbound practices, to address the challenges posed by eco-innovation.

Concerning the challenges raised by eco-innovation, environmental deterioration is one of the most urgent ones and has led to firms' increased interest in investing in sustainable innovations to allow sustainable production [3,11]. Therefore, eco-innovation emerges as the result of integrating the philosophy of sustainability in the context of the business innovation process, and is a type of innovation that in each phase of the life-cycle ensures solid reduction of risks, pollution and energy consumption/use compared to other alternatives [12].

Eco-innovation occurs at the micro level, i.e., at the individual level, where capturing value is characterised by the position of power, unique experiences and absorptive capacity, and also at the macro level, i.e., in the ecosystem. At the same time, open innovation, besides occurring at the micro level also occurs at the meso level, the network level characterised by knowledge-sharing and building partnerships. Consequently, open innovation towards eco-innovation, i.e., open eco-innovation, is related to generating innovations that use inbound and outbound knowledge flows to stimulate internal innovation created with external stakeholders, aiming to have an impact on and create value for society and the environment, thereby working at the micro and macro levels and requiring a flow of knowledge from various actors [4,13–15].

The complexity of knowledge that is an integral part of many eco-innovations stimulates the need to work with partners through open innovation [16], but the development of eco-innovations using open innovation has not yet been well studied [17]. The literature also shows a gap regarding the knowledge sources used in eco-innovation, since it requires a multiple and heterogeneous set of sources, larger and more diverse that other technologies [18]. Therefore, those industries are forced to go far beyond their core competences and the acquisition of external knowledge is a basic factor [19]. This perspective leads to the importance of understanding the channels and sources of information through which eco-innovative firms benefit from external flows [20].

It is extremely important to clarify those channels and how companies absorb and exploit them, for different reasons: first of all, the need to give scientific support to political decision-makers in elaborating instruments to maximize the use of open innovation systems in the environmental domain, stimulating firms' interaction, capacities and learning; secondly, the fact that firms can open up to external sources of knowledge, helping them to overcome their internal limitations and the lack of resources and intangibles to support the creation of eco-innovations; and thirdly, the possibility of guiding these firms, in collaboration with external stakeholders responsible for the environment, to be more sustainable [21–26]. Therefore, this article contributes to analysis of the effects of open innovation and public policies oriented to generating eco-innovations in companies, based on assessment of inbound and outbound practices. Specifically, it also contributes to extending the very limited knowledge about the effects of inbound and outbound practices of open innovation and public policies on the eco-innovative performance of bioeconomy and non-bioeconomy firms, by using secondary data from the Community Innovation Survey (CIS)—CIS 2010. To do so, samples of firms from Slovakia, Spain, Hungary, Italy, Portugal and the Czech Republic are studied, considered moderately innovative countries by the Innovation Union Scoreboard 2010.

The article is structured as follows. It begins with a review of the literature on the inbound and outbound practices of open innovation, and eco-innovation, resulting in the proposal of a conceptual

model. This is followed by the methodology, database, sample, the variables used and the method of estimation. Then the results are analysed and discussed. Finally, the conclusions, limitations and implications are presented.

2. Literature Review

2.1. Open Innovation: Inbound and Outbound Practices

The basic idea for the appearance of open innovation lies in the fact that organisations are not able to innovate in isolation, having to engage with different types of partners in order to acquire new ideas and resources to be able to become competitive [27,28]. Stimulated by Chesbrough [6] and contrasting with the conventional view of innovation as an activity within the firm's limits, open innovation refers to the flow of valuable ideas originating inside or outside the firm, and this can reach the market also from inside or outside the firm. In other words, open innovation assumes that firms should make use of not only external sources for innovation and external paths to the market, but also internal knowledge through external paths to the market [29].

Reflecting on what had been learnt from practising open innovation and trying to emphasize the intentional nature of knowledge flows leaving and entering the firm [30], the concept was revised by Chesbrough, Vanhaverbeke and West [13], and open innovation came to be regarded as the intentional use of internal and external knowledge flows to accelerate internal innovation and expand markets for the external use of innovation. For Vrande et al. [31], the intentional exit of knowledge or exploitation of technology causes innovation activities to raise existing technological capacities outside the organisation's limits, while intentional entry or exploration of technology is related to innovation activities which capture and obtain benefits arising from external sources of knowledge to improve current technological developments. In other words, exploitation involves undertakings based on internal knowledge, internal licensing of intellectual property and involvement with employees, while exploration implies customer involvement in the process of innovation, external licensing of intellectual property and tertiarization of R&D.

Dahlander and Gann [27] argue that open innovation deals with ideas that arise and can be commercialized inside or outside the firm, since this implies firms using multiple sources of knowledge, accelerating the advantages of developing internal ideas that are not immediately launched on the market. Later, Chesbrough and Bogers [32] say that open innovation is a distributed process of innovation and based on knowledge flows managed through organisational borders. Open innovation is a concept in evolution and is no longer the linear and bilateral process of transactions and collaborations within the innovation process, but a wider, dynamic process with network and multi-collaborative participation in an ecosystem of open innovation (European Commission, 2016) [33].

According to Dahlander and Gann [27], open innovation presents advantages such as: (i) reflecting social and economic changes in work patterns where professionals seek a portfolio of careers, rather than a job for life with a single employer, meaning firms must find new ways to access talents who perhaps do not want to be employed by others exclusively and directly; (ii) exploitation of the benefits of globalization, which has expanded the size of the market, allowing a greater division of work; (iii) improved market institutions, such as intellectual property rights, risk capital and technological standards, allowing the organisation to exchange ideas; and (iv) new technology allows new forms of collaboration and coordination, contributing to reducing geographical distances. On the other hand, Manzini et al. [34] also mentioned the potential disadvantages of open innovation, which include the loss of control, increased managerial and organisational complexity, and consequently, increased costs.

In addition, various studies, highlighted among them Laursen and Salter [35], Rothaermel and Deeds [36], Rohrbeck et al. [37] and Chiang and Hung [38], draw attention to the positive and negative effects of open innovation systems. As positive effects, Laursen and Salter [35], Rothaermel and Deeds [36] and Chiang and Hung [38] mention increased profit, R&D performance, product innovation, greater access to sources of knowledge and the success of new products on the market. Concerning

negative effects, Laursen and Salter [35], Rothaermel and Deeds [36] and Torkkeli et al. [39] highlight excessive costs of exploration for external flows of knowledge, the struggle to control knowledge assets and negative attitudes towards open innovation.

Open innovation practices are in accordance with the diversity of forms used in knowledge transfer, i.e., inbound and outbound, also known as outside-in and inside-out, respectively. In inbound OI, knowledge flows from the external environment towards the focal firm; vice versa, in outbound OI, knowledge internally developed flows in the direction of the external environment [40]. In the literature on open innovation, inbound and outbound are designated in various ways, for example: principal processes of open innovation in R&D management [41]; dimension as to the direction of the knowledge flow in relation to the firm [27]; and also typology of open innovation [42].

The systematization proposed by Dahlander and Gann [27] concerning open innovation presents two main dimensions: direction of the knowledge flow in relation to the firm (inbound x outbound) and the involvement of monetary exchange (non-pecuniary vs. pecuniary), and consequently of the main types of openness: sourcing; acquiring; revealing; and selling; is among the most commonly used and is therefore adopted in this study as the operational model of the components of inbound and outbound practices (Figure 1). Inbound practices are types of openness in which external resources can be provided to the internal environment with firms being able to do this via sourcing and acquiring. Sourcing corresponds to an entry that does not involve non-pecuniary exchanges, with an implicit synergy between internal processes and open information available without strict financial liabilities. On the other hand, acquiring is an entry that involves pecuniary exchanges, including all forms of purchasing technology and R&D efforts. Regarding outbound practices, these are types of openness whereby internal resources can be provided to the external environment. Firms can do this via revealing and selling. Revealing is an exit that does not involve pecuniary exchange and concerns knowledge-sharing with the partner network without immediate financial benefit, whereas selling corresponds to an exit involving monetary exchange, allowing total leverage of the R&D investment in partnership with actors able to bring those results to the market.

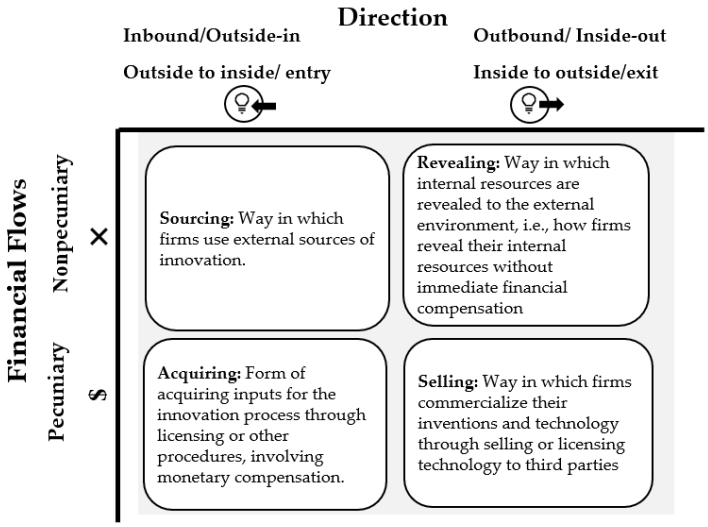

Figure 1. Operational model of forms of inbound and outbound practices. **Source:** Own elaboration, from Chesbrough and Brunswicker [43].

It is noted that Chesbrough and Brunswicker [43] use these same forms of inbound and outbound practices for a different purpose, i.e., to classify explicitly the range of open innovation activities, and not to propose and operationalize forms of inbound and outbound practices as is done in this study. With the due difference, it is noted that taking as reference the first column of Figure 1, the inbound activities including non-pecuniary exchanges characterised by the supply of ideas and external knowledge from suppliers, clients, the competition, consultants, universities, research organisations

and others, also require the development of synergistic relations, understood as indispensable for internal innovation and mutually beneficial management of open information flows with the partners involved, competitors or otherwise [44]. Here, activities involve, for example, client and consumer co-creation processes, crowdsourcing, consortia financed by the public sector in R&D or informal networking. In addition, inbound activities that cover pecuniary exchanges involve acquiring a typology of openness, through the acquisition of inventions and inputs via informal and formal monetary connections, involving an accumulation of competences. These activities include entry licensing of intellectual property, R&D contracts, intermediaries specialized in open innovation, competitions for ideas and start-ups, innovation awards for suppliers or university research grants.

Moving to the second column of Figure 1, non-pecuniary outbound practices imply a revealing strategy, through which the firm reveals its internal resources to the external environment, sharing knowledge with external partners, but without any financial benefit, with this generally occurring in situations where there are highly uncertain regimes of appropriability and where the protection of inventions is too costly. This practice includes participation in public norms or donations to common goods or non-profit organisations. In relation to pecuniary outbound practices, these are characterised by a form of selling that can involve both out-licensing of intellectual property and the sale of products on the market, assuming total leverage of investment in R&D collaboration with partners able to spread the results [45]. These strategies can cover a number of activities, namely joint-ventures, spin-offs, incubation and the sale of market-ready products.

Among the activities presented above are firms that will choose which activities are more convenient for their purposes, i.e., inbound, transmitting internal use of external knowledge; outbound, external use of internal knowledge, and also mixed open innovation, requiring active collaboration between partners to innovate, resulting from orchestrating inbound and outbound activities. Firm activities aiming to make efficient use of inbound and outbound activities need consideration, not only concerning how to absorb resources, but also the use of solutions to enable sustainable actions on firms' internal and external borders. Moreover, the success of open innovation practices is generally associated with increased efficiency in the general performance of the firm's innovation, where the gain mechanics, regarding performance, include the internal and external increase of a set of competences and access to external sources of knowledge, as well as the internal resource economy and the generation of profits from internal intellectual property which is not directly incorporated in market products [43].

In an environment of open innovation, it is essential for firms to develop various dynamic resources to manage their resources effectively, both internally and externally. Conventionally, in the inbound context, there is emphasis on absorption capacity, as suggested by Cohen and Levinthal [46], but as firms began to be increasingly interested in selling their technology as a form of outbound innovation, research on open innovation has evolved to mainly consider the inbound process, study the outbound process and emphasize the need for knowledge capacities [47,48]. The inventive capacity in technology exchange markets, as well as the desorptive capacity of licensors is reflected in the studies by Shin et al. [47] and Hu et al. [49] on outbound open innovation.

Inventive capacity refers to firms' internal capacity to create innovative knowledge, after identifying unsatisfied needs in the market, influenced by the firm's existing knowledge stock in the form of its patent portfolio and citations of patents and technological range [50]. The protection of patents is therefore a strategic advantage for firms to benefit from outbound open innovation, especially in certain technological domains, for example, the pharmaceutical or biotechnological sectors, since this can reduce transaction costs in technological markets. As technological knowledge is of an intangible nature, its licensing is characterised by its complexity, with greater disturbances due to being involved in technology-intensive environments. Furthermore, the licence of a contract with external partners is highly complex due to information asymmetry [51,52]. In this competitive scenario, the firm's inventive capacity is related to licensors' fame and the firm's set of competences and resources owned. That resource stock makes firms' inventive capacity more interesting for licensees, including firms'

patent stock and high-level researchers, and contributes to better collective awareness of potential partners and collaborators. In addition, licensees are interested in increasing their own prestige by establishing partnerships with this type of licensor who has strong inventive capacities, ensuring a relationship of mutual trust. Briefly, licensees with greater inventive capacity also have a greater chance of out-licensing their technology [53,54].

Desorptive capacity refers to firms' capacity to indicate and exploit opportunities for technology transfer, based on their outbound strategies [47]. This capacity is linked to the firm's dynamic capacities, meaning that they intentionally generate, increase and change their resource bases. It is also related to the firm's previous experiences with out-licensing contracts, which in a market characterised by high turbulence, is a major advantage in obtaining lower transaction costs. These competences learned from the firm's previous technological trajectories are extremely important in turbulent and competitive environments [47].

According to Shin et al. [47], and Nonaka [54], knowledge management processes are differentiated by exploitation, exploration and retention of knowledge so that for firms to be able to retain knowledge from inter-firm collaboration, there must be connection capacity. Connection capacity is related to the alliance and firms' relational capacities, ensuring licensors' priority access to external sources of knowledge without complete acquisition. The larger the set of connections and collaborators firms have, the easier the process of managing relations between these external parties tends to be, achieving greater benefits from maintaining external knowledge [47,55].

Firms are coming under increased pressure to combine resources from multiple stakeholders due to growing innovation rates, highly complex global supply chains and in a growing context of catastrophes and environmental problems. Moreover, environmental problems can limit the firm's growth, leading to the attractiveness of sustainable innovations requiring diverse interactions and sources of knowledge [47,54]. In addition, in the area of sustainable, environmentally friendly innovation, in particular, to create eco-innovation, the role of the main users and suppliers is crucial. This arises from the basic assumption that eco-innovation results from highly complex, systemic and interlinked processes involving a set of different stakeholders, as well as the interactions of multiple internal and external factors, transmitting practices of inbound, outbound and combined innovation [56].

2.2. Eco-Innovation

Given the growing concern about the environmental impact of products and their resource-intensive production, a greater number of companies have considered introducing eco-innovation to create simultaneously economic and environmental value [2,3,57]. The concept of eco-innovation relates to organizational sustainability and circular economies [58]. Fussler and James [59] were the first to use the term eco-innovation, defining it as a new product or new process that adds value for the business or the client, with a significant reduction in environmental impacts.

The most widely accepted definition of eco-innovation is the one proposed by Kemp and Pearson [12] and complemented by Horbach et al. [15], according to whom eco-innovation is the production, application or exploitation of goods, services, production processes, organisational structures or management methods that represent something new for the firm or user over their life-cycle, representing the reduction of environmental risks and pollution, implying the limitation of negative impacts resulting from intensive use of resources, for example, energy, compared to relevant alternative options. Consequently, eco-innovation directed to openness, i.e., open innovation, is related to the creation of innovations that use inbound and outbound flows of knowledge to stimulate internal innovation created with external stakeholders, aiming to have an impact and create value for society and the environment, thereby working at both the micro and macro levels and requiring a flow of knowledge from various actors [4,13–15].

In the scenario of open eco-innovation, the mentality shared between partners is the entry and exit of knowledge and its exploitation to attain objectives intrinsically connected with the ecosystem [60].

Consequently, at the macro level, i.e., the ecosystem, capturing environmental value involves a broad and complex set of stakeholders, besides producers and consumers, i.e., eco-systemic performance, the global impact, the regional environment and social value [61]. Here, value includes not only the generation of economic value, but also social and ecological value, for example, improvement in the quality of air and water, preservation of resources, employment growth, reduced pollution and others [62,63]. In this connection, at the meso level, i.e., the network level characterised by sharing knowledge and forming partnerships, there is a diversity of organisational cultures, network structures in development and unbalanced power conflicts that can affect decision-making processes at the micro (firm) level, which in turn can also influence the macro level, the environmental and social level [14].

The systemic nature of eco-innovation requires a multi-faceted knowledge base which is unlikely to exist in one company [15]. It also needs a network of stakeholders to satisfy the permeability between the firm and the external environment, with each stakeholder having the role of bringing knowledge to be exploited and generating value added for all the partners involved [60]. This is not just a question of how each stakeholder creates and captures value added, but mainly how the group of partners acts as a knowledge base for the purpose of generating and capturing value among partners linked through a collaborative scheme of open innovation focused on a common context and mission, so as to contribute to an agenda of industrial sustainability [64,65].

As eco-innovation is of a multi-faceted nature, the literature has witnessed the emergence of an approach centred on the determinant drivers of eco-innovation, structured in three main branches: (i) market attraction; (ii) technological impulse; and (iii) regulatory effects.

Concerning the perspective of market attraction, previous studies indicate that eco-innovation results from expectations of turnover, the search for new eco-innovations; previous economic performance; and benefits for the consumer [66–69].

In relation to the technological impulse, the literature has concentrated on firms' R&D activities, amount of knowledge capital, organisational systems and management focused on environmental innovations [66,70–72].

Concerning regulatory effects, previous studies were concentrated on the roles of environmental policies and standards for the adoption of eco-innovation [73]. Regarding this last aspect, this study has a particularly relevant role, in that it contributes to enriching the analysis of the effects of adopting public policies on eco-innovative performance.

Not only the determinants, but also the enablers of eco-innovation have been subject to much debate. For example, the industrial innovation links and inter-firm networks can enable eco-innovation, providing firms with resources that disguise the lack of scale economies [74]. In addition, partnerships formed with stakeholders outside firms' supply chain, such as knowledge-intensive business services (KIBS), research institutions, universities and competitors, are even more important for eco-innovation than for other types of innovation [75]. The same effect is noted in cooperation for innovation in R&D [76], where universities and business suppliers are indicated as the main partners when considering the impact of eco-innovations.

Of great importance is how firms practising eco-innovation look for external sources of knowledge to be able to innovate, which can be characterised by the extent and depth of the search for knowledge [35]. The extent corresponds to the set of sources available to firms, noting that eco-innovative firms have wider, more diversified sources, since they need more external sources of knowledge than other innovative firms [77,78].

Eco-innovative companies are therefore forced into different regulatory frameworks, which means preparation to cope with knowledge requirements; for example, the need to have scientific knowledge from universities and R&D laboratories about the materials and processes to use, the set of environmental norms to consider when innovating in collaboration with agencies and suppliers' ability to provide sustainable production inputs. All this diversity in the supply of knowledge reveals the necessary extent of eco-innovation, which cannot be found in just a few knowledge suppliers. Moreover, eco-innovation is polyvalent, requiring a combination of various objectives and their internal

harmonization. These diverse objectives cover production efficiency, quality, environmental standards and others, requiring additional sources of knowledge from diverse origins [18,19,79].

It is also important to address the depth of eco-innovations that involve providing depth to external knowledge sources. In the specific case of eco-innovations, external knowledge sources are generally distant from firms' core business, having access to alternative knowledge, which can be an obstacle to its implementation. So firms must undertake deeper interaction with the acquisition of knowledge, in order to enable absorption and exploitation of viable knowledge [78]. Eco-innovative companies also have difficulty in finding the right cooperation partner, needing a deeper, sustainable inter-connection after forming the collaboration, which increases the importance of selection and maintenance processes for these firms [80].

Not only can eco-innovative firms' search for knowledge sources be difficult, but also management and exploitation of these sources can be complex and costly, in that not only distance is important but also that the shortage of green management competences to exploit them. Here, the absorption capacity of eco-innovative firms, i.e., the innovator's capacity to detect, acquire and exploit knowledge sources, is fundamental. Social integration mechanisms increase the absorption capacity of eco-innovative firms, through use of their organisational capacities, as occurs with the capacity for connection and socialization, which stimulate communication flows and favour the external spread of knowledge and its very socialization [8,81].

2.3. Design of the Research Hypotheses and the Conceptual Model

Based on the discussion present in the literature reviewed above, a renewed research framework was designed regarding inbound and outbound open innovation practices and also public policies, as explanatory variables of eco-innovative performance as the dependent variable. Concerning inbound open innovation practices related to the transmission and internal use of external knowledge, these practices are measured through the intermediary of various (non-pecuniary) sources and also through (pecuniary) acquisition. As for outbound open innovation practices corresponding to external use of internal knowledge, these are measured either through (non-pecuniary) revealing or (pecuniary) selling. The dependent variable is product innovation and process innovation, resulting in eco-innovative performance. In addition, company size and whether in 2010 it belonged to a group of companies are included in the study as control variables.

Returning to inbound practices, concerning sourcing, the empirical study by Ketata et al. [82] with data on 1.124 German companies reveals that the extent and depth of knowledge sources improve sustainable innovations. Ghisetti et al. [60], using the CIS 2006–2008 for 11 European countries, obtain similar results, confirming that knowledge sources (extent and depth) are positively associated with the introduction of eco-innovation, but they do not distinguish between the influences of different sources of information.

The interests and needs of all partners in a highly uncertain and complex environment make external knowledge sources particularly important [82]. According to Laursen and Salter [35], actors such as suppliers, users and competitors are seen as market sources providing a soft opening, with the share of information without entering into bonding, juridical agreements. Market sources help companies to gather and absorb information about customers' needs and demand, as well as exploiting information about their competitors' eco-innovation programmes. Authors such as Geffen and Rothenberg [83] and Kammerer [68] mention that knowledge coming from suppliers and customers is relevant for eco-innovation. Regarding the effect of these sources, in both process and product innovation, Marzucchi and Montresor [84] find that the knowledge coming from suppliers, clients, competitors, industrial associations, fairs and conferences is highly relevant for all types of eco-innovation, but especially for process innovations related to reducing material or energy, as far as end-of-pipe technology or the implementation of ecological products is concerned.

For institutional sources of information based on knowledge arising from science and related more directly to national innovation systems (universities, governments and public research institutes),

Bönte and Dienes [85] detected a significantly positive influence of institutional sources (universities) on eco-innovation. Despite the empirical evidence of a positive influence of knowledge from institutional sources on innovation, only Marzucchi and Montresor [84] and Del Río et al. [86] differentiate its effects in terms of process innovation and product innovation. Marzucchi and Montresor [84] show that these sources influence environmentally efficient technology, such as processes to reduce material or energy consumption, but not the introduction of environmental products. In contrast, Del Río et al. [86] only find positive influences of knowledge from institutional sources on product innovation.

By forming partnerships with other firms or non-commercial organisations, companies improve their capacity to introduce new processes or products. Those that engage in cooperation gain access to the knowledge or synergistic skills of complementary partners and capitalize on entry spillovers [87–89], so that they can have access to technology which otherwise could not be acquired on the market [90], aiming to reduce the multiplication of R&D efforts; lessen the risks and costs associated with innovation projects [91]; and obtain economies of scale [88]. Firms can contribute to creating a strong and densified network of multilevel cooperation and alliances involving all the stakeholders [92]. Studies on the influence of cooperation in R&D on eco-innovation produce converging results. For example, for De Marchi [76], cooperation is more important for the introduction of eco-innovations than for any other type of innovation. Collaborative networks with universities and public institutions are also essential stimulants of all types of eco-innovation [93,94]. Horbach et al. [18] observe a significant influence of cooperation in R&D, but only for processes with an environmental benefit for firms related to dangerous substances.

Still in relation to inbound practices, but now concerning acquiring, which is pecuniary entry of innovation, Rouvien [95] states that the acquisition of new equipment, as a form of incorporated knowledge, should mainly stimulate process innovations. Companies can also gain access to an external knowledge base through developing external R&D sub-contracting operations or acquiring technology from external partners, i.e., via licensing. These operations involve pecuniary exchanges for ideas acquired externally, but can also complement the firm's internal knowledge, increasing the likelihood of successful exploitation and exploration. Unlike the acquisition of patented licences, external acquisition of R&D is beneficial only if it shows some complementarity to the focal firm's internal knowledge [89].

However, empirical evidence of the influence of external R&D on eco-innovation is contradictory. The longitudinal study by Horbach [67] shows that improved technological capacities through R&D activities triggers eco-innovations. Later, Horbach et al. [15,18] find a slightly negative influence, but only in process innovations with environmental benefits in related areas, such as energy, dangerous material and recycling. De Marchi [76] and Marzucchi and Montresor [84] do not find a significant influence of acquiring external knowledge, in the form of patents or licences, on eco-innovation. According to Bönte and Dienes [85] and Li-Ying et al. [96], firms involved in external R&D are less likely to introduce process innovations regarding energy and material efficiency. That theoretical statement is corroborated by transversal results obtained at the company level which reveal significant complementarities between internal and external R&D for products, but not for process innovations [97]. In the light of these considerations and previous empirical results, the following research hypothesis is considered:

Hypothesis 1 (H1). *Inbound open innovation practices have a positive relation with eco-innovative performance.*

Hypothesis 1a (H1a). *Non-pecuniary flows of inbound open innovation practices have a positive relation with eco-innovative performance.*

Hypothesis 1b (H1b). *Pecuniary flows of inbound open innovation practices have a positive relation with eco-innovative performance.*

Concerning outbound open innovation practices, previous empirical evidence is very scarce [98], with this being a neglected issue [99]. Nuvolari [100] proposes that companies reveal their ideas to their competitors without any identifiable negative consequence. Through revealing, using a marketing lens, firms can increase their reputation [101], goodwill [102], brand recognition [103] and their target-public [104].

From the technological point of view, revealing can be beneficial when companies use crowdsourcing as a source of knowledge, instead of trying to solve problems internally or hiring a specialist supplier [105,106]. Revealing is also used to obtain feedback from customers [107], manufacturers and even competitors [108].

Still, in relation to inbound practices, but regarding selling, which involves pecuniary exchanges and activities such as licensing, Inauen and Schenker-Wicki [109] find a significant impact on the performance of innovation accompanied by a greater probability of radical innovations that can be critically important for R&D managers. Mazzola et al. [110] also underline the fact that external licensing produces a positive impact on innovation performance. This leads to the following research hypothesis:

Hypothesis 2 (H2). *Outbound open innovation practices have a positive relation with eco-innovative performance.*

Hypothesis 2a (H2a). *Non-pecuniary flows of outbound open innovation practices have a positive relation with eco-innovative performance.*

Hypothesis 2b (H2b). *Pecuniary flows of outbound open innovation practices have a positive relation with eco-innovative performance.*

Study of the literature on the determinant factors of eco-innovation has highlighted the assumed importance of public policies in designing incentives able to promote strategic conduct and practices tending to reinforce eco-innovation [15,111]. Popp [112] found empirical evidence that firms' decisions on innovation were stimulated mainly through national regulations, but eco-innovations can also be motivated by international regulations, as in the case of air pollutants in Japan, where the catalyst of eco-innovation was regulations in the United States of America [113].

Horbach [67] concluded that public policies and the motivation to make cost savings are the main determinant factors of eco-innovation. Jänicke [111] argues that intelligent regulations have an important role in political competition for eco-innovation and can be identified as a driver of eco-innovation. The study by Khanna et al. [114], making a distinction for environmental regulation, proposes that anticipated regulation and the presence of complementary assets are important vehicles for the creation of incentives to innovation. Another important contribution to this debate was made by Kammerer [68], by revealing that the effects of regulations on innovation vary according to the area of environmental impact. Therefore, a distinction should be made between eco-innovations aiming to improve the energy efficiency of materials and the reduction of greenhouse gas emissions (GGE), contributing to improved recycling or reducing negative environmental impacts on the water and the soil. More recently, Ghisetti and Rennings [115] and Triguero et al. [116] indicate the positive effect of public support in the form of subsidies for firms adopting environmental innovation. Leitão et al. [117], in the context of Portuguese high-tech companies, also find a positive effect of public policies. This leads to the following hypothesis:

Hypothesis 3 (H3). *Public policies have a positive relation with eco-innovative performance.*

Considering the complexity of the theoretical references reviewed and the set of previous empirical evidence, Figure 2 proposes a conceptual model of analysis, which aims to simplify the analysis framework developed in the following section of this study, exploring the relations between the inbound and outbound practices of open innovation, public policies and eco-innovative performance.

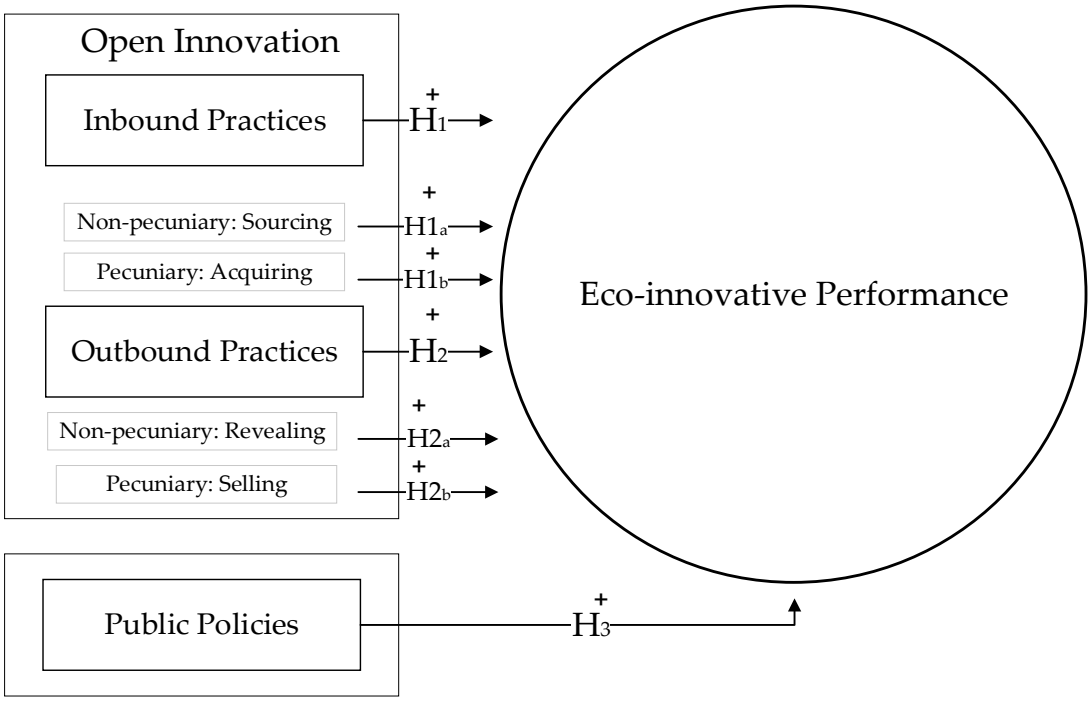

Figure 2. Inbound and Outbound Practices of Open Innovation, Public Policies and Firms' Eco-Innovative Performance: a proposed conceptual model. **Source:** Own elaboration.

3. Methodology

3.1. Database and Sample

The database used for this research corresponds to the Community Innovation Survey 2010, which provides information about sectors' innovation capacity according to firm type, about the different types of innovation and various aspects of an innovation's development, such as objectives, information sources, public financing, expenditure on innovation, etc. The data available are used to produce samples for European Union (EU) member states considered moderate innovators, according to the results of the 2010 edition of the Innovation Union Scoreboard. In the empirical test, only the available data from CIS 2010 were used, for a group of moderate innovators (cf. Figure 3), namely: Slovakia (SK); Spain (ES); Hungary (HU); Italy (IT); Portugal (PT); and the Czech Republic (CZ). For that reason, it was not possible to include the other countries in the group, namely: Greece (GR); Malta (MT); and Poland (PL).

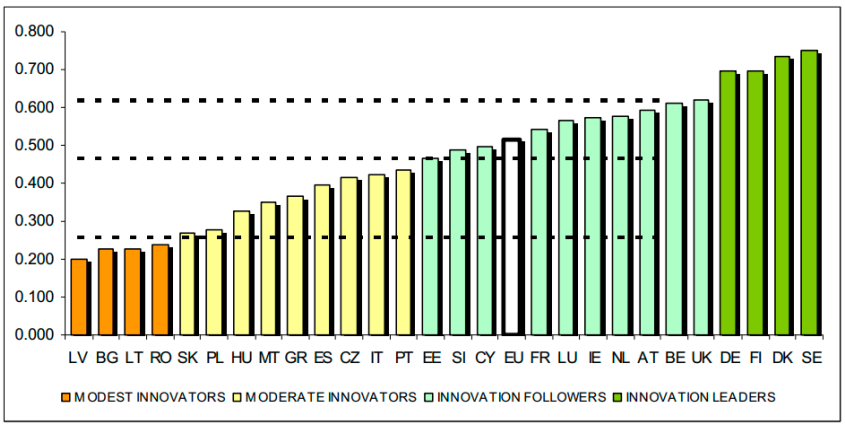

Figure 3. Innovation Performance of European Union Member States. **Source:** Innovation Union Scoreboard 2010.

Analysis of the bio-economy has attracted growing interest among academics [118–120] policy-makers [121,122] and institutions of international reference, including the European Commission [123]. This justifies the focus of the present empirical study on the bioeconomy sector, with the available data being used to produce six samples of firms related to the bioeconomy, located in: Slovakia; Spain; Hungary; Italy; Portugal; and the Czech Republic. Following the official statistical classification of economic activities in the EU (NACE rev. 2), the total sample was divided into "bioeconomy firms"; and "non-bioeconomy firms" (see Table A1, in Appendix A). It is noted that bioeconomy covers the production of renewable biological resources and the conversion of these resources and waste flows into products with value added, such as food, animal fodder, biological-based products and EU bio-energy [123]. The bioeconomy requires vast amounts of biomass that current value chains cannot provide [124].

For better understanding of the total samples and the sub-samples of bioeconomy and non-bioeconomy firms, Table 1 shows the number of "bioeconomy firms" and "non-bioeconomy firms", as well as presents their composition in relation to firm size. The Slovakian sample contains 2363 companies of which 343 are bioeconomy firms and 2050 non-bioeconomy firms; the Spanish sample is made up of 34,550 firms, 6279 being bioeconomy and 28,271 non-bioeconomy; the Hungarian sample contains 4683 firms, 1228 being bioeconomy and 3410 non-bioeconomy; the Italian sample contains 18,328 firms, 2280 being bioeconomy and 16,048 non-bioeconomy; and the Portuguese sample contains 6060 firms, 1223 being bioeconomy and 4937 non-bioeconomy. The sample of 5151 Czech firms is made up of 1435 bioeconomy firms and 3716 non-bioeconomy. In general, both bioeconomy and non-bioeconomy firms are small or medium-sized.

Table 1. Distribution of firms according to bioeconomy and non-bioeconomy and their distribution by size for total samples and sub-samples.

Country	Sample	Firms		Size (Total Employees)					
		N°	%	<50	%	50–249	%	250 e +	%
Slovakia	Total	2363	100	1169	49.47	836	35.38	358	15.15
	Bioeconomy	313	100	110	35.14	123	39.30	80	25.56
	Non-Bioeconomy	2050	100	1059	51.66	713	34.78	278	13.56
Spain	Total	34,550	100	21,438	62.05	9753	28.23	3359	9.72
	Bioeconomy	6279	100	3992	63.58	1872	29.81	415	6.61
	Non-Bioeconomy	28,271	100	17,446	61.71	7881	27.88	2944	10.41
Hungary	Total	4638	100	2455	52.93	1618	34.89	565	12.18
	Bioeconomy	1228	100	585	47.64	498	40.55	145	11.81
	Non-Bioeconomy	3410	100	1870	54.84	1120	32.84	420	12.32
Italy	Total	18,328	100	12,991	70.88	3540	19.31	1703	9.29
	Bioeconomy	2280	100	1447	63.46	554	24.30	279	12.24
	Non-Bioeconomy	16,048	100	11,544	71.93	2986	18.61	1424	8.87
Portugal	Total	6160	100	3956	64.22	1684	27.34	520	8.44
	Bioeconomy	1223	100	706	57.73	400	32.71	104	8.50
	Non-Bioeconomy	4937	100	3237	65.57	1824	26.01	416	8.43
Czech Republic	Total	5151	100	2806	54.47	1373	26.66	972	18.87
	Bioeconomy	1435	100	805	56.10	427	29.76	203	14.15
	Non-Bioeconomy	3716	100	2001	53.85	946	25.46	769	20.69

Source: Own elaboration based on data collected from the Community Innovation Survey-CIS 2010.

The sub-samples of "bioeconomy firms" and "non-bioeconomy firms" were tested empirically, using multivariate tobit regression models, considering the research hypotheses resulting from the previous literature review and the subsequent design of the conceptual model proposed here.

3.2. Variables and Model Specification

This study focuses on the effects of inbound and outbound practices of open innovation and public policies on eco-innovative performance. Therefore, the variables of "Reduce the material and energy used by unit produced" (ORME) and "Reduce the environmental impact" (OREI), with the original designation (in brackets) of the variables of CIS 2010, are the dependent variables resulting in eco-innovative performance. These are polytomous variables that analyse the importance, in the period 2008 to 2010, of the firm introducing innovative products and processes, i.e., equal to 0, if the introduction of new or significantly improved products or processes was irrelevant; equal to 1 if the introduction of product or process innovation was of low importance, and 2 if the introduction of new or significantly improved products or processes was of medium-high importance.

As for the independent variables, this research used the variables associated with inbound and outbound practices of open innovation as well as public policies. Besides the dependent and independent variables, included as control variables were: size (SIZE_3); and group (GP). For the size variable (SIZE_3), firms with up to 50 employees are small firms, those with between 50 and 249 employees are medium-sized and those with 250 or more employees are large firms. The group variable (GP) can determine the influence of belonging to a group of firms.

As already mentioned, to estimate the proposed model and test empirically the research hypotheses and the conceptual model, this study adopted the tobit regression model. The tobit regression model developed by Tobin [125] belongs to a class of econometric techniques traditionally considered as censored regression models [126], having been projected to estimate relations between variables when there is censor on the left or right of the dependent variable. The tobit model can be written as a latent regression model $y = x\beta + \varepsilon$ with a continuous result that is observed or not observed. Following Cong [127], the result observed for the observation i is defined as:

$$y_i^* = \begin{cases} y_i \ se \ a < y_i < b \\ a \ se \ y_i \leq a \\ b \ se \ y_i \geq b \end{cases} \quad (1)$$

where: a is the lower censor limit and b is the upper censure limit. The tobit model assumes that the error term follows normal distribution; $\varepsilon \sim N(0; \sigma^2)$. Depending on the issue in question, the amount of interest in a tobit model can be the censored result y_i^* or the result without censor y_i.

Amemiya [128] extended the univariate tobit model to the multivariate model, creating the MVTOBIT, its usefulness lying mainly in that dependent variables are determined as a whole. In this study, the tobit multivariate model is used to explain two types of eco-innovation: process eco-innovation: y_{1i}^*; and product eco-innovation: y_{2i}^*. The multivariate tobit assumes that the density of articulation function behaves with a normal multivariate distribution with a mean of zero, constant variances and a constant correlation between the error terms. Using the MVTOBIT command on STATA the parameters β are estimated using the maximum likelihood method.

The variables in the conceptual model are presented in Table 2 below.

Table 2. Dependent, independent and control variables.

Variables			Description
Dependent	Eco-innovation—Process	ORME	Reduce the material and energy used per unit produced
	Eco-innovation—Product	OREI	Reduce the environmental impact
Independent	Inbound—Non-pecuniary	SCOM	Source of information: Competitors or other firms in the same sector of activity
		SINS	Source of information: Consultants, laboratories or private R&D institutions
		SGMT	Source of information: State Laboratories or other public bodies with R&D activities
		SJOU	Source of information: Scientific journals and technical/professional/commercial publications
		SPRO	Source of information: Professional or business associations
		CO11	Cooperation with firms in the same group
		CO21	Cooperation with suppliers of equipment, material, components or software
		CO31	Clients or consumers
		CO41	Competitors or other firms in the same sector of activity
		CO51	Consultants, laboratories or private R&D institutions
		CO61	Universities and other higher education institutions
		CO71	State Laboratories or other public bodies with R&D activities
	Inbound—Pecuniary	RRDEX	External acquisition of R&D activities
		RMAC	Acquisition of machinery, equipment and software
		ROEK	Acquisition of other external knowledge
	Outbound—Non-Pecuniary	MNFIN	Non-financial incentives for employees to develop new ideas, such as: free time and recognition
	Outbound—Pecuniary	RRDIN	R&D activities carried out inside the firm
		INPDGD	New or significantly improved goods
		INPDSV	New or significantly improved services
		INPSPD	New or significantly improved manufacturing or production methods
		INPSLG	New or significantly improved logistics, delivery or distribution methods of the production factors or final products
		INPSSU	New or significantly improved support activities for company processes
		ORGBUP	The firm introduced new business practices in the organisation of procedures
		ORGWKP	The firm introduced new methods of organising responsibilities and decision-making
		ORGEXR	The firm introduced new methods of organising external relations with other firms or institutions
		MKTDGP	The firm introduced significant changes in the aspects or packing of goods or services
		MKTPDP	The firm introduced new techniques or means of communication to promote goods or services
		MKTPDL	The firm introduced new distribution methods or new sales channels
		MKTPRI	The firm introduced new pricing policies for products
	Public Policies	FUNLOC	Public financial support from: Local or Regional Administration
		FUNGMT	Public financial support from: Central Administration (agencies or ministries, through government programmes)
		FUNEU	Public financial support from: European Union
		FUNRTD	The firm participated in the 6th and 7th framework programme of the EU for R&D
	Controls	SIZE_3	Total number of people working for the firm in 2010
		GP	In 2010, the firm was part of a group of firms

Source: Own elaboration.

4. Results

The multivariate tobit model was estimated for the sub-samples of bioeconomy and non-bioeconomy for the moderately innovative countries. For each sub-sample, the dependent variables identified and described above (ORME and OREI) were used. It is noted that for better understanding of the data, descriptive statistics were calculated for both sub-samples of the different countries studied, but they are not presented here to limit the length of the document. The VIF (Variance Inflation Factor) was also calculated, and according to Hair et al. [129], as values of $VIF < 10$ were obtained, potential problems of multicollinearity are not identified.

The estimation process began with the test of a univariate tobit model, which was found to be statistically significant for all sub-samples and countries represented here. For example, 313 bioeconomy firms in Slovakia show a logarithmic likelihood of −131.113 (ORME) and −127.207 (OREI); with a p value of 0.000 and 0.000, respectively, corroborating that the models are statistically significant. For the 2050 non-bioeconomy firms in Slovakia, with a logarithmic likelihood of −1068.832 (ORME) and −1158.779 (OREI) and the p value of 0.000 and 0.000, the models are also statistically significant. The same model, i.e., univariate tobit, is seen to be statistically significant when considering the other countries, and the same goes for the multivariate tobit model which is statistically significant for the sub-samples and all the countries studied (cf. Table 3)

Table 3. Validity and statistical significance of the models.

		Univariate				**Multivariate**			
		Bioeconomy		**Non-Bioeconomy**		**Bioeconomy**		**Non-Bioeconomy**	
		ORME	**OREI**	**ORME**	**OREI**	**ORME**	**OREI**	**ORME**	**OREI**
Slovakia	a.	−131. 113	−127.207	−1068,83	−1158.779	−260.891	−260.891	−1559.421	−1559.421
	b.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spain	a.	−5427.962	−5381.417	−21,808.94	−21,581.971	−9451.366	−9451.366	−31,205.92	−31,205.92
	b.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hungary	a.	−638.782	−715.703	−2088.466	−2284.845	−957.933	−957.933	−2835.724	−2835.724
	b.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Italy	a.	−1869.155	−1866.256	−10,214.656	−11,264.631	−3114.255	−3114.355	−14,185.097	−14,185.097
	b.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Portugal	a.	−982.547	−957.4881	−4411.592	−5422.166	−1578.583	−1578.583	−7337.374	−7337.374
	b.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Czech Republic	a.	−890.611	−959.084	−2760.673	−2835.036	−1514.236	−1514.236	−4158.295	−4158.295
	b.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Legend: a. Log Likelihood | **b.** P-Value. **Source:** Own elaboration.

Assuming that all the models are statistically significant, the results found are now presented, according to the response axes expressed in the research hypotheses, opting to present only the results of estimating the multivariate tobit model, for two reasons. Firstly, the dependent variable being tested for different values, and secondly, not finding substantial differences in the results obtained and in the associated levels of statistical significance and maximum likelihood.

Continuing to present the results for the multivariate tobit (Table A2 in Appendix B) and beginning with Slovakian bioeconomy firms, inbound practices are significant and have a positive influence on process (ORME) and product (OREI) innovation. Outbound practices involving a non-pecuniary flow do not show significant evidence. Pecuniaries are significant and have a positive effect on process (ORME) and product (OREI) innovation. As for public policies, these show mixed significant evidence in process innovation (ORME), with the FUNLOC variable having a positive influence and the FUNGMT variable having a negative influence. In product innovation (OREI), public policies are significant and have a positive effect. Firm size (SIZE) is only significant with a positive influence on product innovation (OREI), with no evidence regarding process innovation (ORME).

The results for Slovakian non-bioeconomy firms show that non-pecuniary inbound practices are significant and have a positive influence on process innovation (ORME), but for product innovation

(OREI) the evidence is mixed. Also non-pecuniary inbound practices are significant, but the evidence is mixed for both process (ORME) and product (OREI) innovation. Non-pecuniary outbound practices do not present significant evidence for either type of innovation, but pecuniaries are significant with a positive influence on process (ORME) and product (OREI)innovation.

Public policies and company size (SIZE) are significant and have a positive influence on process (ORME) and product (OREI) innovation

The results for Spanish bioeconomy firms demonstrate that inbound practices are significant with a positive influence on process (ORME) and product (OREI) innovation. Non-pecuniary outbound innovation practices do not present evidence of their behaviour, whereas pecuniaries have a significant influence on both types of innovation. Public policies have a positive significant relation with process innovation (ORME) with mixed evidence regarding product innovation (OREI). The fact of a company belonging to a group (GP) has a positive influence on process (ORME) and product (OREI) innovation.

The results for Spanish non-bioeconomy firms are almost identical to those found for bioeconomy firms, except for the fact of a firm belonging to a group (GP) not presenting evidence of significance for process innovation (ORME), despite having a significantly positive influence on product innovation (OREI).

The results for Hungarian bioeconomy firms indicate that inbound practices have a positive and significant influence on process innovation (ORME) and product innovation (OREI). Regarding non-pecuniary outbound practices, there is no evidence of their behaviour and pecuniaries are significant and have a positive influence on both innovations. Public policies are significant and have a positive influence on process (ORME) and product (OREI) innovation. The fact of a company belonging to a group (GP) has a positive influence on process innovation (ORME), but this is not found for product innovation (OREI).

The results for Hungarian non-bioeconomy firms indicate that inbound practices have a positive and significant influence on process innovation (ORME) and product innovation (OREI). As for outbound practices, these influence process innovation (ORME) positively and significantly, but there is no evidence of their effect on product innovation (OREI). Pecuniary outbound practices are significant with a positive influence on process (ORME) and product (OREI) innovation. Public policies present mixed evidence on process innovation (ORME) and although significant have a negative influence on product innovation (OREI). Company size (SIZE) is significant and shows a positive influence on process (ORME) and product innovation (OREI).

The results for Italian bioeconomy firms show that non-pecuniary inbound practices have a positive, significant influence on process (ORME) and product (OREI) innovation. Regarding pecuniary inbound practices, these are significant and have a positive influence on process innovation (ORME) with the evidence being mixed for product innovation (OREI). Non-pecuniary outbound practices show no evidence, whereas pecuniaries are significant with a positive influence on both types of innovation. As for public policies, these are significant with a positive influence on process innovation (ORME), with the evidence being mixed for product innovation (OREI). Company size (SIZE) is significant and has a positive influence on both process (ORME) and product (OREI) innovation.

The results for Italian non-bioeconomy firms show that inbound practices are significant and have a positive influence on process (ORME) and product (OREI) innovation. Non-pecuniary outbound practices show no evidence, while pecuniaries are significant with a positive influence on both types of innovation. As for public policies, these are significant, having a positive influence on process (ORME) and product (OREI) innovation. Firm size (SIZE) is significant and has a positive influence on both process (ORME) and product (OREI) innovation, but the fact of a firm belonging to a group (GP) is significant and has a negative influence on product innovation (OREI).

The results for Portuguese bioeconomy firms show that inbound practices are significant and have a positive influence on process (ORME) and product (OREI) innovation. Non-pecuniary outbound practices do not show statistical evidence, while pecuniaries are significant and have a positive influence on both types of innovation. As for public policies, these present mixed evidence regarding process

innovation (ORME) and product innovation (OREI). For firm size (SIZE) and belonging to a group (GP), no significant evidence is found.

The results for Portuguese non-bioeconomy firms reveal that non-pecuniary inbound practices are significant and have a positive influence on process (ORME) and product (OREI) innovation. In addition, pecuniary inbound practices are significant and with a positive influence on process innovation (ORME), while for product innovation (OREI) the evidence is mixed. Non-pecuniary outbound practices show no evidence with associated statistical significance, while pecuniaries are significant and have a positive influence on both types of innovation. As for public policies, these show no evidence in relation to process innovation (ORME), while for product innovation (OREI) the evidence is mixed. Firm size (SIZE), is significant and has a positive influence on process (ORME) and product (OREI) innovation.

The results for bioeconomy firms in the Czech Republic show that inbound and outbound innovation practices are significant and have a positive influence on process (ORME) and product (OREI) innovation. As for public policies, these are significant and have a positive influence on both types of innovation. Firm size (SIZE) is significant and has a positive influence on process innovation (ORME), but regarding product innovation (OREI) no significant evidence was found.

The results for Czech non-bioeconomy firms show that inbound practices are significant and have a positive influence on process (ORME) and product (OREI) innovation. Non-pecuniary inbound practices show no evidence of their behaviour, whereas pecuniaries are significant and have a positive influence on both types of innovation. As for public policies, these are significant and have a negative influence on both types of innovation. Firm size (SIZE) is significant and has a positive influence on process (ORME) and product (OREI) innovation.

In general, the results of the multivariate tobit suggest that inbound practices, involving either non-pecuniary or pecuniary flows, have a positive influence on eco-innovative performance. It should be noted that the results obtained for the multivariate tobit suggest non-pecuniaries show mixed evidence, as occurs with non-bioeconomy firms in Slovakia. Regarding outbound practices, these also have a positive influence on eco-innovative performance, but those involving non-pecuniary flows only reveal a significantly positive influence for bioeconomy firms in Slovakia and also for non-bioeconomy firms in Hungary and only in relation to process innovation. As for public policies, these show a positive influence on eco-innovative performance, despite detecting various cases of mixed evidence and even a negative influence. Besides the above, the multivariate tobit also suggests that size (SIZE) has a positive influence on eco-innovative performance. A summary of the results is presented in Appendix B, Table A2. For a more detailed analysis, consult Tables A3–A8, also in Appendix B.

5. Discussion

After presenting the results, they will now be discussed in relation to the research hypotheses. Considering Hypothesis H1, proposing a positive effect of inbound open innovation practices on eco-innovative performance. This hypothesis is confirmed for the bioeconomy and non-bioeconomy sub-samples and for all countries studied. H1 is not rejected, since for the different countries various significant variables stand out. For example, for Slovakia, sources of information from competitors or other firms in the same sector of activity (SCOM) on the sourcing side, and acquisition of other external knowledge (ROEK) on the acquiring side, are always significant, whether focusing on process or product innovation, or bioeconomy or non-bioeconomy firms. For Spain, all the sources considered in this study, i.e., sources of information in competitors or other firms in the same sector of activity (SCOM); consultants, laboratories or private R&D institutions (SINS) State laboratories or other public bodies (SGMT); information from scientific journals and technical/professional publications (SJOU) and professional or business associations (SPRO) on the sourcing side, and external acquisition of R&D activities (RRDEX) and acquisition of machinery, equipment and software (RMAC) on the acquiring side, are always significant, whether focusing on process or product innovation or bioeconomy or non-bioeconomy firms. In Hungary too, sources of information in competitors or other firms in

the same sector of activity (SCOM) on the sourcing side, and external acquisition of R&D activities (RRDEX), as well as the acquisition of machinery, equipment and software (RMAC) on the acquiring side, are always significant, whether focusing on process or product innovation, or bioeconomy or non-bioeconomy firms. In Italy, sources of information in competitors or other firms in the same sector of activity (SCOM); consultants, laboratories or private R&D institutions (SINS) information from scientific journals and technical/professional publications (SJOU) and professional or business associations (SPRO), on the sourcing side, and external acquisition of R&D activities (RRDEX) and the acquisition of machinery, equipment and software (RMAC), on the acquiring side, are always significant in process or product innovation, for both types of firms. In Portugal, sources of information in competitors or other firms in the same sector of activity (SCOM); consultants, laboratories or private R&D institutions (SINS) information from scientific journals and technical/professional publications (SJOU) and professional or business associations (SPRO) are always significant, in process or product innovation and in bioeconomy or non-bioeconomy firms. In Portugal, on the acquiring side, the acquisition of machinery, equipment and software (RMAC) has a significantly positive effect on eco-innovation, considering the results of the multivariate tobit model. For the Czech Republic, sources of information in scientific journals and technical/professional publications (SJOU) on the sourcing side, and the acquisition of machinery, equipment and software (RMAC) on the acquiring side, are always significant in process or product innovation and whatever the type of firm considered.

The results are in line with previous studies by Geffen and Rothenberg [83] and Kammerer [68], who state that knowledge coming from suppliers and clients is relevant for eco-innovation. Bönte and Dienes [85] also mention that institutional sources (universities) have a significant influence on eco-innovation. At the same time, considering the result of De Marchi [76], who underlines that cooperation is more important for the introduction of eco-innovations that other types of innovation, the results obtained here contribute to ratifying the importance of cooperation for eco-innovation. This claim is supported by the following variables: cooperation with firms in the same group (CO11); clients or consumers (CO31); competitors or other firms in the same sector of activity (CO41); consultants, laboratories or private R&D institutions (CO51); universities or other higher education institutions: (CO61); State laboratories or other public bodies with R&D activities (CO71). For inbound practices, on the acquiring side, Rouvinen [95] argues that the acquisition of new equipment, as a form of incorporated knowledge, should encourage mainly process innovations.

Hypothesis H2 assumes a positive relation between outbound open innovation practices and eco-innovative performance. A positive effect is confirmed for bioeconomy and non-bioeconomy firms. In greater detail, on the revealing side, for Slovakia, Spain and Portugal, there is no significant evidence in favour of revealing, but for Italy, the results indicate a negative relation and for Hungary and the Czech Republic the results indicate a positive relation. Therefore, the results are in line with Nuvolari [100], who concludes that firms reveal their ideas to their competitors with no identifiable negative consequence. On the selling side, highlighted are variables such as R&D activities carried out in the firm (RRDIN); new or significantly improved goods (INPDGD); new or significantly improved services (INPDSV); among others. So the results agree with the previous findings of Cassiman and Veugelers [130], who state that when firms invest more in internal R&D activities, they become more prepared to absorb external knowledge, and therefore, innovate.

Horbach [67], Kesidou and Demirel [131], Horbach et al. [15] and Triguero et al. [94] are examples of studies agreeing with the third hypothesis of this research, i.e., public policies have a positive relation with eco-innovative performance. In this study, H3 is not rejected for bioeconomy and non-bioeconomy firms.

6. Conclusions

This study analyses the effects of inbound and outbound open innovation practices and public policies on eco-innovative performance, for bioeconomy and non-bioeconomy firms in moderately innovative countries. Inbound practices consider the non-pecuniary flows corresponding

to sourcing and the pecuniary flows corresponding to acquiring, while outbound practices consider the non-pecuniary flows corresponding to revealing and pecuniary flows corresponding to selling.

In terms of general results, inbound practices of the sourcing and acquiring type, outbound practices of the revealing and selling type and public policies show a positive relation with eco-innovative performance. Concerning inbound practices of the sourcing type, for bioeconomy firms, from the results obtained, all the sources considered in this study, i.e., sources of information in competitors or other firms in the same sector of activity (SCOM); consultants, laboratories or private R&D institutions (SINS) State laboratories or other public bodies (SGMT); information from scientific journals and technical/professional publications (SJOU) and professional or business associations (SPRO) are significant for both process and product innovation (see the results, for example, for bioeconomy firms in Spain and Portugal.

Cooperative relations are also incorporated in inbound practices of the sourcing type, revealing that for bioeconomy firms, cooperation with firms in the same group (CO11) is only positive in product innovation in Portugal and cooperation with universities or other higher education institutions (CO61) and negative in process innovation in Slovakia. For inbound practices of the sourcing type, and for non-bioeconomy firms, the results are similar, for example, in the specific case of Spain, all the sources considered in this study are positive and significant, for both process and product innovation.

Still for inbound practices, but of the acquiring type and for bioeconomy firms, it should be noted that external acquisition of R&D activities (RRDEX) is positive and significant in both process and product innovation, as shown by the results for Slovakia and Hungary, although for Italy the results show a significantly negative influence, for both types of innovation. Also, for inbound practices of the acquiring type, but for non-bioeconomy firms, the acquisition of machinery, equipment and software (RMAC), they always show a positive and significant influence on process and product innovation.

Regarding outbound practices, the revealing mode for bioeconomy firms operationalized through non-financial incentives for employees to develop new ideas, such as: free time and recognition (MNFIN); this is seen to be significant and positive for both process and product innovation as observed from the results for the Czech Republic. Considering outbound practices, the revealing mode for non-bioeconomy firms through non-financial incentives for employees to develop new ideas, such as: free time and recognition (MNFIN); is also significant and positive, in terms of process and product innovation, observed through the results obtained for Hungary.

For selling mode outbound practices and for bioeconomy and non-bioeconomy firms, R&D activities carried out in the firm (RRDIN); and new or significantly improved goods (INPDGD) show a positive and significant relation in both process and product innovation.

The empirical evidence now obtained sheds new light and provides both theoretical and empirical contributions to the positive and significant influence of open innovation outbound practices on eco-innovation; in particular, the pecuniary flows, since for non-pecuniary ones, it was only possible to detect a positive relationship for the cases of Bioeconomy companies of the Czech Republic and non-Bioeconomy companies of Hungary, which are two examples of transition economies with an upward innovative profile on the pathway to the maturity of open innovation processes.

These results advance the still limited knowledge about the importance associated with the implementation of open innovation outbound practices on the eco-innovative performance of companies belonging to a strategic sector, worldwide; that is, the Bioeconomy sector, since the previous empirical evidence regarding this sector, with increased strategic importance in the face of global climate change, are still scarce or even neglected in the literature and references on open innovation.

As for public policies, public financial support coming from Local or Regional Administration (FUNLOC) is shown to be significant and positive for both process and product innovation, as confirmed for Spain and Italy. Besides the influences described above, size and the fact of the firm belonging to a group, they also produce a significantly positive influence on process and product innovation.

This study has some implications. In terms of theory, it improves understanding of inbound and outbound practices. For example, besides considering sourcing, inbound practices also consider acquiring, and besides considering revealing, outbound practices also incorporate selling.

Regarding implications for innovation managers, they should consider the need to balance internal and external knowledge that improves environmental performance, because as argued by Rothaermel and Alexandre [132], the level of ambidexterity can allow firms to configure and raise their internal and external knowledge resources, in terms of the influence of technology supply strategies on environmental performance. Concerning public policies, public financing bodies should consider the results presented here, for example, in decision-making processes that imply the allocation of funds for activities aiming for open eco-innovation.

One of the main limitations of this study arises from the lack of information observed in successive surveys from CIS 2012 until the most recent CIS 2018, particularly for the variables referring to eco-innovative performance. Another limitation is the lack of studies of reference addressing the effects of, above all, outbound practices on eco-innovative performance. Another concerns the analysis being limited to bioeconomy and non-bioeconomy firms, as industrial and service companies could also be interesting, considering their prominence in economies.

Finally, in terms of future research, it would be interesting to study in greater depth the effects associated with inbound and outbound open innovation practices and public policies on the eco-innovative performance of firms with different profiles of technological intensity, based on a comparison between modest, moderate, follower and leader countries in innovation.

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Conflicts of Interest: The authors declare there are no conflict of interest.

Appendix A

Table A1. Sector classification: National Classification of Economic Activities-NACE Rev.2.

Classification	Description	NACE Code Rev.2
Bioeconomy firms	Agriculture	A01
	Forestry	A02
	Fishing and aquaculture	A03
	Production of food, drinks and tobacco	C10; C11; C12
	Production of biologically-based cloth, clothing and leather	C13 *; C14 *; C15
	Production of wooden products and wooden furniture	C16; C31 *
	Production of paper	C17
	Production of biologically-based chemical products; pharmaceutical products and plastic and rubber	C20 *; C21 *; C22 *
	Bio-ethanol production	C2014 *
	Bio-diesel production	C2059 *
	Bio-electricity production	D3511 *
Non-bioeconomy firms	Mines and quarries	B05-B09
	Printing and reproduction of recorded media	C18
	Production of coke and derivatives of refined oil	C19
	Production of non-metallic mineral products; basic metals; manufactured metal products, except machinery and equipment; computer, electronic and optical products; electrical equipment; machines and equipment n.e.c; vehicles, trailers and semi-trailers; other manufacturing; repair and installation of machines and equipment	C23; C24; C25; C26; C27; C28; C29; C30; C32; C33
	Supply of electricity, gas, steam and air conditioning	D35
	Supply of water; drains, waste management and remediation	E36-E39
	Construction	F41-45
	Wholesale and retail commerce; Repair of motor vehicles and motorbikes	G45-G47
	Transport and storage	H49-H53
	Accommodation activities and food services	I55-I56
	Information and communication	J58-J63
	Financial activities and insurance	K64-K66
	Real estate activities	L68-
	Professional, scientific and technical activities	M69-M75
	Administrative and support service activities	N77-N82
	Public administration and defence and obligatory social security	O84
	Education	P85
	Human health and social work activities	Q86-Q88
	Arts, entertainment and recreation	R90-R93
	Other activities and services	S94-S96
	Activities of households as employers; undifferentiated producing activities of private households for own use	T97-T97
	Activities of foreign organisations and entities	U99

*. Hybrid sector.

Appendix B

Table A2. Results of the multivariate tobit model: Summary.

Samples	Independent	Dependent	Slovakia		Spain		Hungary		Italy		Portugal		Czech Republic	
			1	2	1	2	1	2	1	2	1	2	1	2
			ORME	OREI	ORME	OREI	ORME	OREI	ORME	OREI	ORME	OREI	ORME	OREI
Bioeconomy	Inbound	Non-pecuniary	+	+	+	+	+	+	+	+	+	+	+	+
	Inbound	Pecuniary	+	+	+	+	+	+	+	+/−	+	+	+	+
	Outbound	Non-pecuniary	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	+	+
	Outbound	Pecuniary	+	+	+	+	+	+	+	+	+	+	+	+
	Public policies		+/−	+	+	+/−	+	+	+	+/−	+/−	+/−	−	+
	Control		✗	+	+	+	+	✗	+	+	✗	✗	+	✗
Non-Bioeconomy	Inbound	Non-pecuniary	+	+/−	+	+	+	+	+	+	+	+	+	+
	Inbound	Pecuniary	+/−	+/−	+	+	+	+	+	+	+	+/−	+	+
	Outbound	Non-pecuniary	✗	✗	✗	✗	+	✗	✗	✗	✗	✗	✗	✗
	Outbound	Pecuniary	+	+	+	+	+	+	+	+	+	+	+	+
	Public policies		+	+	+	+/−	+/−	−	+	+	✗	+/−	−	−
	Control		+	+	✗	+	+	+	+	+/−	+	+	+	+

Legend: 1. Process innovation **| 2.** Product innovation. **Source:** Own elaboration.

Table A3. Estimation results of multivariate tobit model Slovakia.

	Bioeconomy		**Non-Bioeconomy**		**Bioeconomy**		**Non-Bioeconomy**	
	ORME		**ORME**		**OREI**		**OREI**	
	Coef	**P**	**Coef**	**P**	**Coef**	**P**	**Coef**	**P**
MNFIN								
RRDIN								
INPDGD	1.420	0.000 ***	0.703	0.000 ***	1.162	0.000 ***	0.935	0.000 ***
INPDSV			0.380	0.001 ***			0.328	0.013 ***
INPSPD	0.580	0.000 ***	0.265	0.019 **	0.706	0.000 ***	0.339	0.012 ***
INPSLG							0.295	0.050 **
INPSSU			0.601	0.000 ***			0.501	0.000 ***
ORGBUP			0.314	0.011 ***			0.481	0.001 ***
ORGWKP								
ORGEXR					−0.429	0.029 **		
MKTDGP			−0.382	0.005 ***			−0.317	0.051 **
MKTPDP								
MKTPDL								
MKTPRI	−0.472	0.020 **	0.230	0.082 *			0.310	0.051 **
SCOM	0.150	0.057 *	0.321	0.000 ***	0.186	0.020 **	0.304	0.000 ***
SINS			0.156	0.019 **				
SGMT								
SJOU	0.334	0.000 ***	0.458	0.000 ***	0.500	0.000 ***	0.458	0.000 ***
SPRO								
CO11								
CO21			0.421	0.015				
CO31			−0.718	0.001 ***			−0.519	0.039 **
CO41			0.356	0.082 *				
CO51			−0.389	0.042 **			−0.405	0.075 *
CO61					−2.380	0.017 **		
CO71								
RRDEX								
RMAC	0.654	0.001 ***	1.178	0.000 ***	0.856	0.000 ***	1.406	0.000 ***
ROEK			−0.255	0.051 **			−0.313	0.045 **
FUNLOC	1.720	0.040 **			2.158	0.011 ***		
FUNGMT	−0.628	0.047 **						
FUNEU			0.575	0.004 ***			0.608	0.010 ***
FUNRTD								
SIZE			0.122	0.045 **	0.261	0.006 ***	0.168	0.024 **
Log Likelihood	−260.891		−1559.421		−260.891		−1559.421	
P-value	0.000		0.000		0.000		0.000	
AIC	671.7824		3268.842		671.7824		3268.842	
BIC	952.7476		3690.762		952.7476		3690.762	

AIC—Akaike Information Criterion; BIC—Schwarz Bayesian Information Criterion. *** 1%; ** 5%; * 10%.

Table A4. Estimation results of multivariate tobit model Spain.

	Bioeconomy		**Non-Bioeconomy**		**Bioeconomy**		**Non-Bioeconomy**	
	ORME		**ORME**		**OREI**		**OREI**	
	Coef	**P**	**Coef**	**P**	**Coef**	**P**	**Coef**	**P**
MNFIN								
RRDIN	0.430	0.000 ***	0.700	0.000 ***	0.631	0.000 ***	0.809	0.000 ***
INPDGD	0.302	0.000 ***	0.532	0.000 ***	0.448	0.000 ***	0.519	0.000 ***
INPDSV								
INPSPD	0.966	0.000 ***	0.914	0.000 ***	0.701	0.000 ***	0.709	0.000 ***
INPSLG			0.187	0.000 ***			0.178	0.000 ***
INPSSU	0.351	0.000 ***	0.618	0.000 ***	0.287	0.000 ***	0.508	0.000 ***
ORGBUP	0.196	0.000 ***	0.118	0.001 ***	0.203	0.000 ***	0.179	0.000 ***
ORGWKP			0.182	0.000 ***			0.201	0.000 ***
ORGEXR	−0.174	0.005 ***	−0.150	0.000 ***	−0.115	0.080 *	−0.155	0.000 ***
MKTDGP								
MKTPDP								
MKTPDL	−0.167	0.011 ***	−0.179	0.000 ***	−0.142	0.042 **	−0.154	0.003 ***
MKTPRI	0.105	0.094 *						
SCOM	0.288	0.000 ***	0.370	0.000 ***	0.304	0.000 ***	0.358	0.000 ***
SINS	0.188	0.000 ***	0.241	0.000 ***	0.189	0.000 ***	0.275	0.000 ***
SGMT	0.135	0.000 ***	0.203	0.000 ***	0.169	0.000 ***	0.217	0.000 ***
SJOU	0.155	0.000 ***	0.178	0.000 ***	0.218	0.000 ***	0.259	0.000 ***
SPRO	0.108	0.000 ***	0.163	0.000 ***	0.134	0.000 ***	0.205	0.000 ***
CO11								
CO21			0.143	0.003 ***			0.168	0.001 ***
CO31			−0.256	0.000 ***			−0.106	0.071 *
CO41			−0.265	0.000 ***	−0.282	0.011 ***	−0.313	0.000 ***
CO51			−0.177	0.002 ***			−0.139	0.020 **
CO61								
CO71	−0.222	0.002 ***	−0.314	0.000 ***	−0.224	0.003 ***	−0.328	0.000 ***
RRDEX			0.145	0.000 ***			0.188	0.000 ***
RMAC	0.403	0.000 ***	0.627	0.000 ***	0.442	0.000 ***	0.591	0.000 ***
ROEK								
FUNLOC	0.163	0.001 ***	0.168	0.000 ***	0.133	0.012 ***	0.221	0.000 ***
FUNGMT			−0.064	0.104 *				
FUNEU					−0.408	0.097 *		
FUNRTD			−0.258	0.039 **			−0.371	0.005 ***
SIZE								
GP	0.217	0.000 ***			0.149	0.001 ***	0.060	0.060 *
Log Likelihood	−9451.366		−31,205.92		−9451.366		−31205.92	
P-value	0.000		0.000		0.000		0.000	
AIC	19,048.73		62,557.85		19,048.73		62,557.85	
BIC	19,541.12		63,160.07		19,541.12		63,160.07	

AIC—Akaike Information Criterion; BIC—Schwarz Bayesian Information Criterion. *** 1%; ** 5%; * 10%.

Table A5. Estimation results of multivariate tobit model Hungary.

	Bioeconomy		**Non-Bioeconomy**		**Bioeconomy**		**Non-Bioeconomy**	
	ORME		**ORME**		**OREI**		**OREI**	
	Coef	**P**	**Coef**	**P**	**Coef**	**P**	**Coef**	**P**
MNFIN			0.075	0.048 **				
RRDIN	0.577	0.000 ***			0.565	0.002 ***	0.963	0.000 ***
INPDGD	0.844	0.000 ***	0.814	0.000 ***	0.880	0.000 ***		
INPDSV							0.461	0.000 ***
INPSPD			0.341	0.000 ***	0.391	0.039 **		
INPSLG							0.420	0.000 ***
INPSSU	0.354	0.037 **	0.442	0.000 ***	0.410	0.059 *		
ORGBUP								
ORGWKP								
ORGEXR								
MKTDGP								
MKTPDP								
MKTPDL	−0.467	0.007 ***					−0.283	0.076 *
MKTPRI	0.371	0.018 ***						
SCOM	0.507	0.000 ***	0.267	0.000 ***	0.575	0.000 ***	0.281	0.000 ***
SINS			0.274	0.000 ***	0.179	0.042 **	0.310	0.000 ***
SGMT							0.184	0.012 ***
SJOU			0.319	0.000 ***	0.275	0.009 ***	0.329	0.000 ***
SPRO	0.149	0.071 *	0.132	0.017 **			0.237	0.001 ***
CO11								
CO21								
CO31								
CO41								
CO51								
CO61								
CO71	−0.466	0.075 *						
RRDEX	0.650	0.000 ***	0.347	0.000 ***	0.569	0.004 ***	0.470	0.000 ***
RMAC	0.687	0.000 ***	1.113	0.000 ***	0.775	0.000 ***	1.258	0.000 ***
ROEK			0.202	0.044 **				
FUNLOC			0.747	0.044 **				
FUNGMT	0.319	0.056 *						
FUNEU	0.316	0.086 *						
FUNRTD	1.477	0.013 ***	−0.764	0.012 ***	1.266	0.0955 *	−1.015	0.009 ***
SIZE			0.148	0.008 ***			0.208	0.004 ***
GP	0.243	0.058 *			0.243	0.058 *		
Log Likelihood	−957.933		−2835.724		−957.933		−2835.724	
P-value	0.000		0.000		0.000		0.000	
AIC	2065.867		5821.447		2065.867		5821.447	
BIC	2449.353		6281.532		2449.353		6281.532	

AIC—Akaike Information Criterion; BIC—Schwarz Bayesian Information Criterion. *** 1%; ** 5%; * 10%.

Table A6. Estimation results of multivariate tobit model Italy.

	Bioeconomy		**Non-Bioeconomy**		**Bioeconomy**		**Non-Bioeconomy**	
	ORME		**ORME**		**OREI**		**OREI**	
	Coef	**P**	**Coef**	**P**	**Coef**	**P**	**Coef**	**P**
MNFIN								
RRDIN	0.530	0.000 ***	0.538	0.000 ***	0.463	0.000 ***	0.494	0.000 ***
INPDGD	0.437	0.000 ***	0.487	0.000 ***	0.573	0.000 ***	0.432	0.000 ***
INPDSV			0.116	0.005 ***			0.267	0.000 ***
INPSPD	0.365	0.000 ***	0.437	0.000 ***	0.480	0.000 ***	0.404	0.000 ***
INPSLG			0.126	0.010 ***			0.108	0.000 ***
INPSSU	0.193	0.010 ***	0.340	0.000 ***			0.264	0.029 ***
ORGBUP								
ORGWKP			0.143	0.001 ***			0.189	0.000 ***
ORGEXR					0.143	0.083 *		
MKTDGP			0.156	0.002 ***			0.146	0.004 ***
MKTPDP								
MKTPDL			−0.228	0.000 ***			−0.152	0.007 ***
MKTPRI								
SCOM	0.203	0.000 ***	0.269	0.000 ***	0.146	0.000 ***	0.209	0.000 ***
SINS	0.160	0.000 ***	0.253	0.000 ***	0.204	0.000 ***	0.253	0.000 ***
SGMT								
SJOU	0.132	0.002 ***	0.222	0.000 ***	0.159	0.000 ***	0.212	0.000 ***
SPRO	0.184	0.000 ***	0.146	0.000 ***	0.168	0.000 ***	0.177	0.000 ***
CO11								
CO21								
CO31								
CO41			−0.362	0.000 ***			−0.291	0.003 ***
CO51					−0.308	0.062 *		
CO61								
CO71								
RRDEX	−0.158	0.064 *			−0.182	0.032 **		
RMAC	1.195	0.000 ***	1.619	0.000 ***	1.231	0.000 ***	1.655	0.000 ***
ROEK	−0.151	0.101 *					−0.130	0.015
FUNLOC	0.279	0.000 ***	0.180	0.001 ***	0.358	0.000 ***	0.269	0.000 ***
FUNGMT			0.187	0.008 ***			0.159	0.025 **
FUNEU								
FUNRTD								
SIZE	0.140	0.0787 *	0.174	0.000 ***			0.159	0.000 ***
GP					0.1162	0.041 **	−0.075	0.090 *
Log Likelihood	−3114.255		−14,185.097		−3114.255		−14,185.097	
P-value	0.000		0.000		0.000		0.000	
AIC	6378.51		28520.19		6378.51		28,520.19	
BIC	6808.405		29,096.44		6808.405		29,096.44	

AIC—Akaike Information Criterion; BIC—Schwarz Bayesian Information Criterion. *** 1%; ** 5%; * 10%.

Table A7. Estimation results of multivariate tobit model Portugal.

	Bioeconomy		**Non-Bioeconomy**		**Bioeconomy**		**Non-Bioeconomy**	
	ORME		**ORME**		**OREI**		**OREI**	
	Coef	**P**	**Coef**	**P**	**Coef**	**P**	**Coef**	**P**
MNFIN								
RRDIN	0.194	0.030 **	0.176	0.001 ***	0.268	0.002 ***	0.115	0.025 **
INPDGD	0.574	0.000 ***	0.457	0.000 ***	0.540	0.000 ***	0.514	0.000 ***
INPDSV							0.142	0.003 ***
INPSPD	0.662	0.000 ***	0.659	0.000 ***	0.641	0.000 ***	0.502	0.000 ***
INPSLG			0.112	0.035 **			0.112	0.035 **
INPSSU	0.321	0.000 ***	0.515	0.000 ***	0.323	0.000 ***	0.555	0.000 ***
ORGBUP					−0.297	0.001 ***		
ORGWKP	0.324	0.000 ***	0.195	0.000 ***	0.314	0.000 ***	0.178	0.001 ***
ORGEXR	−0.205	0.046 **						
MKTDGP	0.176	0.038 **			0.230	0.005 ***	0.120	0.023 **
MKTPDP	−0.164	0.077 *						
MKTPDL	−0.222	0.059 *	−0.136	0.033 **	−0.199	0.083 *		
MKTPRI	0.250	0.008 ***			0.212	0.022 *		
SCOM	0.290	0.000 ***	0.282	0.000 ***	0.260	0.000 ***	0.239	0.000 ***
SINS	0.105	0.034 **	0.129	0.000 ***	0.124	0.010	0.126	0.000 ***
SGMT								
SJOU	0.196	0.000 ***	0.161	0.000 ***	0.221	0.000 ***	0.165	0.000 ***
SPRO	0.093	0.066 **	0.282	0.000 ***	0.099	0.045 **	0.276	0.000 ***
CO11								
CO21					−0.274	0.071 *		
CO31								
CO41								
CO51			−0.298	0.003 ***				
CO61								
CO71								
RRDEX								
RMAC	0.746	0.000 ***	0.699	0.000 ***	0.671	0.000 ***	0.648	0.000 ***
ROEK							−0.123	0.045 **
FUNLOC	0.586	0.007 ***			0.667	0.002 ***	0.313	0.034 **
FUNGMT	−0.198	0.040 **			−0.200	0.033 **	0.105	0.071 *
FUNEU							−0.197	0.038 **
FUNRTD								
SIZE			0.082	0.015			0.072	0.033 **
GP								
Log Likelihood	−1578.583		−7337.374		−1578.583		−7337.374	
P-value	0.000		0.000		0.000		0.000	
AIC	3307.166		3307.166		3307.166		3307.166	
BIC	3690.346		3690.346		3690.346		3690.346	

AIC—Akaike Information Criterion; BIC—Schwarz Bayesian Information Criterion. *** 1%; ** 5%; * 10%.

Table A8. Estimation results of multivariate tobit model Czech Republic.

	Bioeconomy		**Non-Bioeconomy**		**Bioeconomy**		**Non-Bioeconomy**	
	ORME		**ORME**		**OREI**		**OREI**	
	Coef	**P**	**Coef**	**P**	**Coef**	**P**	**Coef**	**P**
MNFIN	0.055	0.055			0.057	0.094 *		
RRDIN	0.353	0.000 ***	0.381	0.000 ***	0.232	0.028 **	0.303	0.000 ***
INPDGD	0.644	0.000 ***	0.332	0.000 ***	0.879	0.000 ***	0.425	0.000 ***
INPDSV								
INPSPD	0.414	0.000 ***	0.338	0.000 ***	0.367	0.000 ***	0.391	0.000 ***
INPSLG			0.278	0.000 ***			0.236	0.004 ***
INPSSU			0.122	0.064 *				
ORGBUP			0.266	0.000 ***			0.249	0.002 ***
ORGWKP	0.163	0.075 *						
ORGEXR								
MKTDGP					−0.202	0.057 *	−0.130	0.099 *
MKTPDP			−0.112	0.098 *				
MKTPDL								
MKTPRI							0.280	0.000 ***
SCOM	0.348	0.000 ***			0.296	0.000 ***	0.192	0.000 ***
SINS			0.101	0.008 ***				
SGMT							0.280	0.000 ***
SJOU	0.339	0.000 ***	0.323	0.000 ***	0.373	0.000 ***	0.192	0.000 ***
SPRO			0.139	0.001 ***	0.156	0.013 ***		
CO11							0.237	0.016 **
CO21					−0.234	0.083 *	−0.318	0.004 ***
CO31			−0.221	0.020 **				
CO41							−0.282	0.023 **
CO51								
CO61								
CO71								
RRDEX								
RMAC	0.837	0.000 ***	1.053	0.000 ***	0.859	0.000 ***	1.138	0.000 ***
ROEK								
FUNLOC								
FUNGMT	−0.224	0.077 *						
FUNEU					0.266	0.066 *		
FUNRTD			−0.258	0.060 *			−0.421	0.008 ***
SIZE	0.123	0.017 **	0.105	0.004 ***			0.131	0.002 ***
GP								
Log Likelihood	−1514.236		−4158.295		−1514.236		−4158.295	
P-value	0.000		0.000		0.000		0.000	
AIC	3178.472		8466.59		3178.472		8466.59	
BIC	3573.641		8933.12		3573.641		8933.12	

AIC—Akaike Information Criterion; BIC—Schwarz Bayesian Information Criterion. *** 1%; ** 5%; * 10%.

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Review

Open Innovation in the Agri-Food Sector: Perspectives from a Systematic Literature Review and a Structured Survey in MSMEs

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Abstract: Open innovation, understood as a strategy for business competitiveness, has experienced growing relevance, even in traditional economic sectors, such as agri-food. This article focuses on the trends and challenges of open innovation applied to the agri-food field, based on two approaches, a Systematic Literature Review (SLR) and a structured survey, answered mainly by micro-, small-, and medium-sized enterprises (MSMEs). For the SLR, the Scopus bibliographic database was chosen. Documents were filtered by type, novelty, and impact factor of the journal (based on the Scimago Rank). The final selection included 50 articles that were deeply analyzed. In addition, the survey was applied to 57 agri-food companies from the department of Nariño (Colombia), establishing a diagnosis of the extent of openness of their collaborative barriers and innovation capacities. The review's results revealed a marked European dominance in this research field. Product co-creation, eco-innovation, and bioeconomy are main fields of interest and application of open innovation. The challenges identified are related to intellectual property rights and effective communication between stakeholders. The survey was successful in establishing a statistically significant correlation between innovation performance and collaboration with external partners. As a conclusion, an open innovation approach can provide dynamism and cohesion in agri-food systems.

Keywords: open innovation; food industry; systematic literature review; structured survey; perspectives and trends

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1. Introduction

Innovation is more frequently perceived as a main determinant of businesses success, effective performance, and organization survival, regardless of their size and influence sector [1,2]. Therefore, administration management researchers and professionals are interested in understanding the underlying drivers of innovation and their effect on business performance [3]. In recent decades, collaboration between diverse external actors has been recognized as an essential element for the generation of new ideas. Likewise, the relevance of the knowledge networks, information flows, importance of learning, and social interaction for innovation have been highlighted [4].

The concept of open innovation was born within this context and was first formulated by the North American professor, Henry Chesbrough, who defined it as "the use of internal and external flows of knowledge to accelerate internal innovation and expand markets for external use of that innovation" [5,6]. Thus, the cornerstone of open innovation is the use of external knowledge by a company in order to accelerate its own internal innovation process [7].

Regarding the agri-food sector, some authors agree that diverse innovation initiatives have been developed with increasing frequency, involving various actors, such as clients,

suppliers, and universities, even though this is considered a segment with low technological developments [7–11]. On the other hand, some authors [12,13] point out that current characteristics of the agri-food sector have made collaborative processes to innovate a necessity. Companies operate in a business environment characterized by increasing competition due to globalization, reduction of trade barriers, and the consolidation of food retailers.

Innovation in the food chain involves the producers of agricultural inputs (such as fertilizers and seeds), growers of agricultural products (such as fruits and vegetables), processors that generate final agri-food products, and the distributors of these products, all of whom play a unique role in the impact of that innovation [14]. Similarly, some reports indicate that the capacity of taking advantage of knowledge based on information technology enables open innovation strategies in the agri-food field [15]. As this is a sector of recent application for open innovation, many of the research works are based on an empirical basis. Therefore, it is necessary to develop systematic literature reviews periodically, which should apply proper methodologies to gather, organize, and update information that has been recently published, contrasting empirical works and case studies of subsectors or regions to find common patterns and teachings that can be applied in a general way to agribusiness.

Within this context, this paper aims at identifying, evaluating, and interpreting, in recent reports, relevant data on open innovation, as well as trends and challenges derived from its use in the agri-food field. Furthermore, seeking to make an additional contribution to this field of study, these papers were contrasted with the innovation situation of the agri-food sector in Nariño, a region in southern Colombia. In this way, the structure of this study is divided into two parts, a Systematic Literature Review and a structured survey answered by 57 companies (mostly MSMEs), which together seek to answer the following research questions:

- RQ1: Which countries and regions lead scientific research in relation to innovation in the agri-food field?
- RQ2: Which authors and journals have the highest number of publications focused on applications of open innovation in agri-food systems?
- RQ3: What are the main topics of interest and application for open innovation within the agri-food sector?
- RQ4: What are the main challenges (detected problems and potential opportunities) that open innovation faces within the agri-food sector?
- RQ5: Regarding the application of open innovation, is the case of the agri-food sector in Nariño consistent with the findings of the SLR?
- RQ6: Is there a positive correlation between open innovation practices and the innovation performance of companies in the agri-food sector?

The results of the present work identified main characteristics and recent trends in studies that were carried out within the sector, as well as the more promising study focuses on open innovation within agri-food systems. Many countries and regions are increasingly using technology roadmaps and open innovation in order to promote sustainable regional development and safeguard both innovation initiatives and competitiveness in global markets [16]. The structured survey left a diagnosis of the capacities of innovation and motivation to collaborate with external partners in a sample that included mainly micro-companies (with less than 10 employees) and young companies. Our results show a statistically significant and positive correlation between innovation capacities of participating companies and their cooperation with various external actors. In conclusion, open innovation benefits competitiveness, cohesion, and technological and research developments of agri-food systems.

2. Conceptual Framework

Innovation is conceived as a business development strategy aimed at the (i) generation of new products and processes, (ii) adaptation of technologies, (iii) advanced training of

workers, and (iv) implementation of changes in the organizational culture, all of which are based on the competitiveness of business and community wellbeing [17]. In a broader context, innovation is beneficial for the overall society, since it improves the productive potentiality of nations, solves existing problems, or needs and plays a central role in the economic development of countries and regions. Thus, innovation gives great relevance to research and development (R&D) activities, especially those nurtured among industrial players [18,19].

Historically, most organizational knowledge was generated internally. However, only a few companies can maintain their competitiveness and innovation nowadays by focusing exclusively on internal sources [20]. Traditional innovation management models have been struggling since the end of the 20th century, mainly due to the significant increase in the number and mobility of highly qualified workers, making it difficult for companies to control and keep their ideas and specialized knowledge [5,18].

This context gave rise to the "Open Innovation" model in 2003, which was originally introduced by Henry Chesbrough in his book: Open Innovation: The New Imperative for Creating and Profiting from Technology [21]. However, Tarde (1890) first formulated the innovation framework in his research work, published more than 200 years ago [22,23]. Unlike the traditional model of integrated vertical innovation [24], where all knowledge is internalized and controlled by the company, the open innovation paradigm is characterized by porous innovation processes and by the strong interaction between the company and its environment [25].

Open innovation assumes that companies can and must use both external and internal ideas as they seek to enhance their innovations [26]. As a result, companies recognize that not all good ideas will come from within the organization and that not all good ideas formulated within organizations can be applied to their business models [18,27]. This concept is increasingly and widely recognized in the academic field and it is being put into practice by various economic sectors, where it is seen as an R&D strategy that is in accordance with the diversification of the consumer demand, business competitiveness, and need for continuous innovation [26,28].

Some authors [29] suggest that open innovation in companies generally pursues three fundamental purposes that constitute elements of analysis from the research perspective: (i) to accelerate internal innovation processes, (ii) to increase opportunities in the market, and (iii) to contribute to companies in the generation of profit. The implementation of this model provides attractive benefits to companies, including shorter releasing time for new products, lower innovation costs, better adaptation to consumer needs of products and services, and shared risk in the development of products and services [2].

Moreover, diverse authors indicate that open innovation in companies usually includes three different dynamics: (i) the inside-out process, which searches for knowledge and technologies abroad to apply them internally; (ii) the outside-in process, which involves the outsourcing and commercialization of internal innovations; and (iii) the coupled or mixed process. These three processes must transcend corporate borders and foster spaces for close collaboration with external actors to introduce mutually beneficial ideas and projects, finding a balance between outside-in and inside-out capacities for the generation of growth opportunities and business value [30–33].

On a previous review [34], which included 291 reports on open innovation and addressed elements of an outside-in model (external sources of innovation), the authors indicate that there is a trend to ignore the importance of business models of each company, despite their central role in the distinction between open innovation and simple inter-collaboration between organizations to innovate. In this respect, open innovation models not only depend on internal factors of the company (such as its R&D capacity or the available technological stock), but there are also other intrinsic factors specifically related to the industry in which each company operates [35].

The authors [28] explain that changes in the National Innovation System (NIS) of the United States catalyzed the emergence of open innovation, mentioning that several

developed nations, including OECD member states, have focused on the open innovation strategy to strengthen and improve their scientific and technological innovation capacities. Finally, in recent years, the concept of open innovation has started to be updated to "Open Innovation 2.0", which eliminates the boundaries between university, industry, government, and community, taking advantage of disruptive technologies, such as cloud computing, the internet of the things, and big data, in order to solve societal challenges in a sustainable and profitable way and with greater speed and proficiency than before [36]. Hence, this new concept connects the open innovation principles with evident social and environmental components, based on sustainability.

Innovation in the agri-food industry depends on multiple actors that interact with each other under specific rules to create new ways of approaching social and economic processes [37]. Thus, the chain of agri-food value describes an articulated set of activities, technologies, resources, and organizations that contribute to the creation, transformation, distribution, and commercialization of a specific product. Therefore, the particular attributes of this sector are key for the application of open innovation strategies [7,8]. In this context, ref. [1] argues that agri-food companies should consider the opportunities that emerge from the adoption of an open innovation approach, which include shorter trade time periods, lower R&D costs, and a better understanding of customer needs. They add that, due to its novelty, there are still many problems inherent to the application of this approach, which must be better addressed to fully integrate this new paradigm into the innovation management process of companies.

3. Materials and Methods

This article is structured in two main parts. First, a Systematic Literature Review (SLR), which aimed to identify the most relevant recent studies on the practical application of the concept of open innovation within the agri-food field. Second, the review was complemented and contrasted with a structured survey applied to a sample of 57 agri-food companies from the department of Nariño (Colombia), which sought to establish a diagnosis of their capacities of innovation and motivation to collaborate with external partners. Figure 1 summarizes the followed methodology.

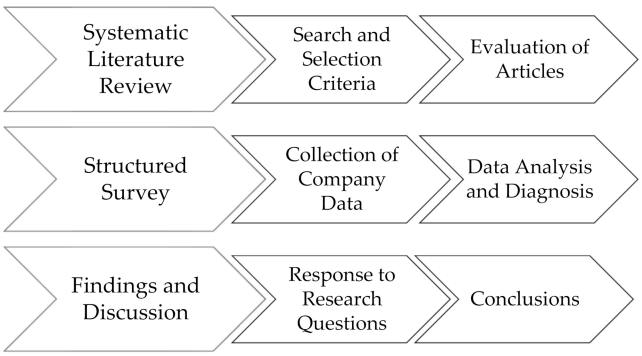


Figure 1. Outline of the study methodology.

The SLR approach originally emerged from the concept of evidence-based medicine (EBM) in the early 1960s, with the aim of improving the decision-making process by reducing the variability of practice or experience [38,39]. The protocol was used to collect, organize, evaluate, and synthesize all the available evidence regarding a phenomenon of interest within a defined period of time [35,38].

The SLR methodology was based on the high standing journals' papers of [35,38], which present reviews focused on co-creation and circular economy, respectively. In turn, the first of these reviews was based, in general terms, on the guidelines established by [40], focused on the conducting of SRL in software engineering, and, in specific terms, on the contributions by [41–43]. For its part, the review from [38] was based on [39], a guide that presents the fundamental elements to take into account SLR focused on administration and

management issues. First, the Scopus bibliographic database was selected as the search engine, a decision based on its international importance and complete multidisciplinary coverage. Subsequently, two search equations were used in the search engine with different approaches to open innovation applications. While the first equation was focused on reports within the primary production sector, the second was centered on studies about the food industry:

Equation (1):

$$\text{TITLE-ABS-KEY (“open innovation” AND agri* OR agro*)} \quad (1)$$

Equation (2):

$$\text{TITLE}-\text{ABS}-\text{KEY (“open innovation” AND food AND NOT agr*)} \quad (2)$$

The asterisk at the end of a term means that the search equation will address all the words that begin with the letters that precede this symbol. The (1) and (2) search equations produced 64 and 107 documents, respectively (a total of 171 reports). Thus, the following selection filters and criteria were established to prioritize the quality of the information:

- Document type: the search was limited only to scientific articles, excluding other bibliographic sources, such as books, book chapters, dissertations, press articles, and repositories of conferences and congresses.
- Novelty of the information: papers published between February 2013 and February 2020 were selected only. This was considered an adequate period to identify current methodologies and significant advances in the field of study, since open innovation processes are closely linked to information and communication technologies (used to connect stakeholders), and therefore, such processes are not unrelated to its accelerated changes.
- Impact and relevance degree: the SCImago SJR (Journal & Country Rank) index and its impact measurement quartiles were used as a reference. Only articles published by journals within the Q1 and Q2 quartiles were chosen.
- Additionally, it was verified that the remaining articles were directly related to the academic field of this research work.

The application of these filters for time, impact, and document time reduced the total number of reports to review from 171 to 50.

After this final selection, the articles were read and evaluated in depth. A research log was then created to efficiently manage the found information. This log was used to classify the articles according to their year of publication, authors, country(s) of affiliation, journal of publication, journal impact factor (SJR), Scimago quartile, and keywords. Likewise, relevant factors for the analysis of the set of documents were included, such as the use of open innovation models and/or platforms, the specific subsector of study or application, the number of companies/actors involved (for case studies), the methodology used, and the problems that were identified. The information loaded into the research log was used as an input to feed the Vantage Point data mining software, which identifies patterns and trends within a set of documents that would be difficult to recognize only through a visual inspection.

On the other hand, the structured survey sample covered 57 companies from the department (state) of Nariño (located at the southern part of Colombia), which belonged to different agri-food links and chains. The questionnaire used was adapted from three previous reports [44–46], the analysis of the 50 articles selected for the systematic literature review, and an additional section related to the impact generated by the new SARS-CoV-2 coronavirus in the innovation of the companies. The questionnaire included 42 questions, divided into the following 11 sections:

1. General data of the organization: name, size (number of employees), seniority, municipality(s) of coverage, and position in the food change

2. Section on general innovation competencies of the company: 7 questions (Yes/No)
3. Section on open innovation platforms and challenges: an informative video summarizing the concept of open innovation and 5 questions (Yes/No)
4. Section on collaborations with external partners in the innovation process (customers): 4 questions, Likert scale (1–5)
5. Section on collaborations with external partners in the innovation process (suppliers): 4 questions, Likert scale (1–5)
6. Section on collaborations with external partners in the innovation process (competitors): 3 questions, Likert scale (1–5)
7. Section on collaborations with external partners in the innovation process (universities, research groups): 4 questions, Likert scale (1–5)
8. Section on collaborations with external partners in the innovation process (independent experts): 4 questions, Likert scale (1–5)
9. Section on performance assessment (innovation performance): 6 questions, Likert scale (1–5)
10. Section on performance assessment (propensity for innovation): 4 questions
11. Section on the effects of the COVID-19 pandemic on innovation: 3 questions with multiple items, Likert scale (3–3)

The complete questionnaire can be consulted in the appendix section of this document. The statistical analysis of the data was carried out through the Statgraphics 18© program.

4. Results and Data Analysis

4.1. Systematic Literature Review

Table 1 shows the document selection process for the two established search questions. Here, the initial results and those obtained after the application of the filters mentioned in the methodology are highlighted. The final number of selected and analyzed articles was 50.

Table 1. Document selection process.

Search Equation	Documents Found	Filter 1: Type and Novelty	Filter 2: Relevance and Impact	Filter 3: Topics
TITLE-ABS-KEY ("open innovation" AND agri* OR agro*)	64	54	31	29
TITLE-ABS-KEY ("open innovation" AND food AND NOT agr*)	107	36	22	21
Total	171	90	53	50

The number of publications from 2013 to February 2020 can be seen in Figure 2. The highest number of studies were registered in 2017, and there seems to be a downward trend from this point.

The information obtained from the final selection of articles and their analysis was fed into The Vantage Point data mining software to answer the research questions.

4.1.1. RQ1: Which Countries and Regions Lead Scientific Research in Relation to Innovation in the Agri-Food Field?

Table 2 shows the first 10 countries with the highest number of publications, adding results from the two equations. As seen, this rank is dominated by European countries that develop research related to open innovation in the agri-food field. Italy is the country with the highest number of publications, with 12 reports [1,7,15,47–55], followed by the Netherlands and Spain, with 7 and 5, respectively.

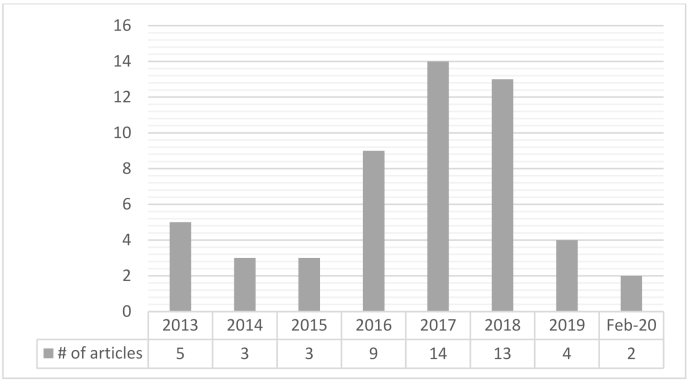


Figure 2. Dynamics of yearly publications.

Table 2. Top 10 countries with the highest number of publications.

Rank	Country	Number of Articles
1	Italy	12
2	Netherlands	7
3	Spain	5
4	Israel	4
5	UK	4
6	Germany	4
7	France	3
8	Hungary	3
9	Australia	2
10	Greece	2

Figure 3 displays academic collaborations between the top 10 countries with the highest number of publications. The graph shows that Italian authors, who published the most, do not seem to create networks with researchers from the other nations. The same situation is observed for authors from Spain and Germany.

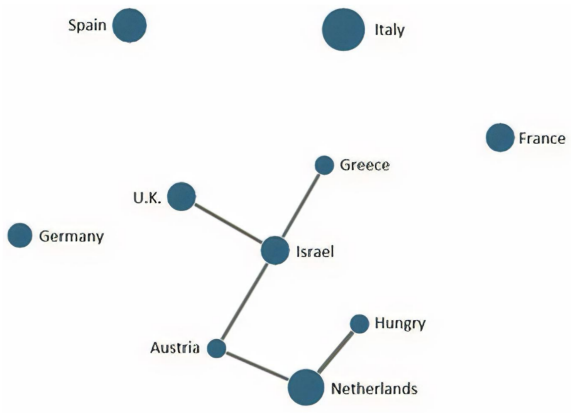


Figure 3. Matrix of academic collaborations between the top 10 countries.

Outside the European continent, Israel is a highly productive country, with four articles [56–59]. The author of all these reports is the professor Sam Saguy, in collaboration with authors from other nations. Some of his studies are focused on curricula of academic programs related to the agri-food sector, indicating that open innovation offers new possibilities and unique opportunities for universities to lead a change from the industrial and academic conservatism that has led the sector to be traditionally considered as having a low-tech intensity. The list also includes reports from Australia [59,60], Canada [61,62], India [8], and Turkey [31].

Surprisingly, the United States, a country considered an agricultural and industrial authority, has only one article from authors that collaborated with French researchers [63]. These authors studied product innovation in agri-food companies and concluded that governments could encourage open innovation through sponsored research or by sharing costs with companies.

4.1.2. RQ2: Which Authors and Journals Have the Highest Number of Publications on Applications of Open Innovation within the Agri-Food Sector?

The journals with the highest impact and number publications can be observed in Figure 4.

Figure 4. Journals with the highest number of publications.

From the selection, the journal with the highest number of articles is the British Food Journal with nine reports [7,14,15,48,52,53,64–66]. This is a journal with more than 120 years of history focused on research applied to the food industry. The Dutch journal Trends in Food Science and Technology is ranked second in the list, with four studies [1,57,58,61], and it is one of the most recognized international peer-reviewed journals, publishing critical reviews and commentaries on current technology, food science, and human nutrition. The American journal, the International Food and Agrobusiness Management Review, is ranked third, with three reports [63,67,68], sharing this position with the British journal, Agricultural systems (Q1) [12,13,69].

Figure 5 displays the authors with the highest number of articles and their academic collaborations. Five work clusters stand out, most with two collaborations. The Israeli author, Sam Saguy, has the highest number of papers, followed by the Hungarian Professor József Tóth, with three published studies [14,68,70] focused on the absorption capacities of open innovation processes by food companies.

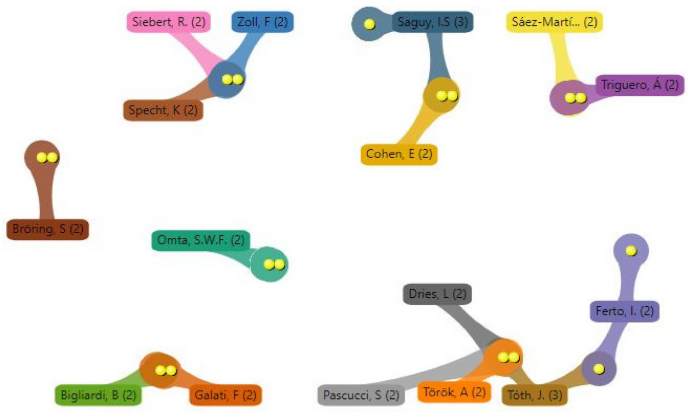


Figure 5. Collaboration clusters among the top 16 main authors.

Authors with more than one article, who were not part of any of the previous clusters, were also identified in the selection. For instance, the Dutch author, S.W.F. Omta,

addresses highly relevant topics, such as intellectual property, cooperative companies, and open innovation platforms [71,72]. Additionally, S. Bröring, a German researcher, studies bioeconomy and barriers to the adoption of open innovation technologies [61,73].

4.1.3. RQ3: What Are the Main Topics of Interest and Application for Open Innovation within the Agri-Food Sector?

A complete assessment of the content of the selected studies was carried out to answer this question, and this information was cross referenced with the set of the most frequent keywords used by the authors included in this review. The data was used to create a cluster diagram from the top 8 keywords (Figure 6).

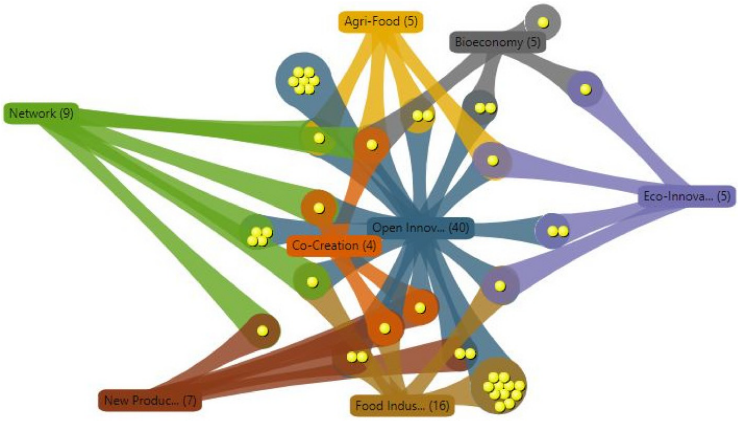


Figure 6. Cluster of relationships between the top 8 keywords.

With seven citations between keywords of the set of documents [30,48,52,64,66,68,72], the development of new products is one of the most recurrent applications for the open innovation approach, especially within the food industry. Eco-innovation is another sub-sector study of growing interest in relation to open innovation [32,33,74]. Finally, bioeconomy stands out within the dataset, especially with studies related to the agricultural sector [69,73,75].

A summary of the most relevant information found regarding these study topics and their relationship with the open innovation approach within the agri-food sector is presented below:

- Development of New Products:

Some studies [76,77] highlight the importance of customers/consumers as key actors in the co-creation of new products, together in association with transformer companies and supported by computerized communication tools. They also show how these processes allow companies to better adapt to market trends. Likewise, the authors emphasize the importance of proper communication and commitment of the parties in this type of association. Other researchers [52] indicate that most empirical studies within the open innovation field include heterogeneous samples of companies from different industrial sectors, despite the fact that innovation is frequently affected by particularities of each specific sector. In this respect, they state that there is a lack of empirical evidence from food and beverage companies involved in open innovation processes.

Those authors [52] also indicate that some companies are reluctant to open up due to traditional values, even though an innovation approach is necessary to remain competitive. Their results show that companies benefit from adopting models to gather external knowledge. Particularly, market-based sources (e.g., customers and provider relationships) are beneficial for incremental innovation and marketing time periods, whereas science-based sources (relationships with academia members and independent experts) are more beneficial for radical innovation. They conclude that the intensity of internal R&D amplifies the benefits.

Research conducted by [30] shows a direct relation between innovation level, external openness, and open innovation management with intellectual property. They suggest that implementing open strategies that involve clients improves overall performance, but they indicate that results depend on the implementation of proper communication channels and a structured model to manage. They conclude that open innovation requires a management model to capture useful and valuable knowledge and, consequently, to assess, in the short and medium term whether organizational changes are worth it.

In their work on how different forms of openness shape the development of new products in the Norwegian cereal industry, [64] conclude that clarity in the interaction with machinery suppliers is key to reaching successful innovations and state that, in practice, companies are more open than they think. Factors such as mutual trust, control, and distribution of assets are positive for openness in innovation processes carried out with suppliers.

Finally, various authors think that open innovation represents an especially attractive opportunity for agri-food SMEs, since they can benefit from the lower economic investment that comes from applying external knowledge and technologies, presiding over or reducing dependence from internal R&D and accelerating the development and release of new products that are more in line with market needs [1,14,49,70,78,79].

- Eco-innovations:

Reference [54] indicates that, even though the reference literature has increased recently, empirical research in traditionally low-technology sectors, such as agri-food, continues to be scarce. Although this sector has traditionally shown little propensity to innovate products and/or processes, especially small companies, the authors argue that many companies have chosen to implement eco-innovations in recent years. References [9,32] attribute this trend to the exploitation of technological changes external to the sector and to a greater environmental awareness of consumers. In addition, they highlight that new technological discoveries in fields such as biotechnology, nutrition, ICT, and health care have facilitated the adoption of eco-innovations in the industry.

In their research, ref. [32] explore the relationship between inbound open knowledge and technology strategies and performance of eco-innovative companies belonging to the food and beverage industry. The authors divided eco-innovative companies into three groups based on their growth and success in the food industry of Spain. As a result, they found that the diversity of collaborators (a wide range of external sources of knowledge) and the joint adoption of eco-innovations in products and processes are positively associated with the probability of achieving a high sales growth. In addition, they highlight that operational flexibility, knowledge-based capacities, and company size are also positively related to the success of eco-innovative companies.

Reference [33] analyzed the influence of open innovation strategies on eco-innovation, assessing the type of innovation (product vs. process) and the degree of novelty (radical vs. incremental). Their study confirms the influence of both market demands and regulatory factors on the general adoption of eco-innovations. Likewise, they showed that the depth of external sources of knowledge is only significant for incremental processes, products, and eco-innovations related to a more efficient use of materials and energy, but not for radical innovations. Finally, the authors [74] highlight the importance of trust in relationships with the involved parties in order to create an atmosphere that encourages the fluid exchange of knowledge between partners, especially when innovations in eco-processes are being developed.

- Bioeconomy:

This concept implies the opportunity and need to reconcile economic growth with an environmentally responsible action and includes all industries and economic sectors that produce, manage, or use biological resources (e.g., agriculture, the food industry, forestry, fishery) [80]. The authors [68] state that the evolution of the bioeconomy is still at a strategic level and point out the need for scientific research to develop a solid concept

and make its implementation manageable. They also argue that value chains, especially those from the agri-food, industrial, and energy sectors, will merge due to a shift to bio-based raw materials, which will generate a mutual dependence and generate new flows of materials and food processing technologies. Finally, they conclude that the creation and exchange of new knowledge between different scientific disciplines requires R&D and innovation within targeted technologies, connecting knowledge-based bioeconomy with the management of technology and innovation.

Study [69] suggests that there is an urgent need to renew the traditional organization and management of agriculture and promote more open, decentralized, contextualized, and participatory approaches for the design and innovation of the sector. They highlight that innovation ecosystems, collective design management, participatory design management, the analysis of systems, and network leadership have become new tools to support sustainable agriculture and foster broader transitions towards the diversity of food systems and circular bioeconomy.

4.1.4. RQ4: What Are the Main Challenges (Detected Problems and Potential Opportunities) That Open Innovation Faces within the Agri-Food Sector?

In terms of challenges of open innovation, several studies [62,72,75] indicate that there are recurrent associativity issues, such as the lack of financial support for technology transfer, diffuse legal frameworks regarding intellectual property of innovations, and communication barriers between parties. These factors affect the progress of open innovation projects and translate into greater spending of time and/or money or even into the failure of the initiatives. In this sense, and from their study on open innovation in urban agricultural systems in Berlin, ref. [81] conclude that correctly establishing the objectives of the projects at the beginning of the associations prevents problems in future phases and uncertainties about expected results.

Another frequent problem observed in some of the reviewed papers [54,62,72] is the handling of intellectual property rights of innovations jointly developed by companies and collaborators in open innovation models. Companies often disregard protecting their organizational knowledge when they engage in these types of collaborations. This situation can increase the vulnerability of the organization to different risks related to open innovation [82], putting the company's competitive advantage at risk, which has a negative impact on its long-term sustainability. In general, a simple way to share intellectual property in the food industry sector would be as follows: the competency provider partner should provide all physical solutions (e.g., ingredients and technology), whereas the receiving party (e.g., the food company) should be in charge of the logical applications for these solutions [1].

The management of intellectual property by companies ranges from confidentiality agreements to patents. Another strategic scheme to reduce risks could be to restrict external sources available to companies so they can focus on the most valuable sources according to the knowledge they need to access, also providing the necessary means to acquire and absorb that knowledge [12].

4.2. Results of Surveys to Agri-Food Companies from Nariño, Colombia

This section seeks to answer the last two research questions, based on the results of the applied questionnaire.

4.2.1. RQ5: Regarding the Application of Open Innovation, Is the Case of the Agri-Food Sector in Nariño Consistent with the Findings of the SLR?

- Characteristics of sample and general innovation capabilities:

Table 3 summarizes the composition of the sample of companies according to their size, years in business, and position in the chain in which they operate. Most companies can be considered SMEs, since only one of the companies surveyed has a plant of employees greater than 250. Furthermore, more than 90% of the companies in the sample

can be considered small or micro companies. In addition, young companies (1–3 years of operation) represent 40.4% of the sample.

Table 3. Role, size, and years of operation of surveyed companies.

Role in the Food Chain	Number of Companies	Percentage (%)
Primary Production	17	29.8
Processing/Transformation	38	66.7
Food Trade/Sales	17	29.8
Size of the Company	**Number of Companies**	**Percentage (%)**
<10 employees	44	77.2
11–50 employees	8	14
51–100 employees	3	5.3
100–250 employees	1	1.8
>250 employees	1	1.8
Years of Operation	**Number of Companies**	**Percentage (%)**
1–3 years	23	40.4
3–7 years	11	19.3
7–12 years	11	19.3
12–20 years	5	8.8
>20 years	7	12.3

On the other hand, Table 4 shows the classification of the surveyed companies according to their main activity. The most common economic subsectors in the companies in the sample were coffee (17.5%), including production, processing, and/or sale of raw coffee or coffee made by their own brand and fruits and vegetables (15.8%); this includes companies dedicated to processing crops such as potatoes, strawberries, and tropical fruits for export.

Table 4. Classification of companies according to their economic activity.

Main Activity/Sector	Number of Companies	Percentage (%)
Coffee and Derivatives	10	17.5%
Other Processed Foods	9	15.8%
Fruit and Vegetable Processing	9	15.8%
Dairy Products	8	14.0%
Chocolate and Confectionery	7	12.3%
Meat Products	4	7.0%
Wholesale Food Trade	3	5.3%
Fried Snacks (Chips)	3	5.3%
Aquaculture	2	3.5%
Frozen or Refrigerated Foods	2	3.5%
Total	57	100%

Dairy companies and chocolate and confectionery companies (mainly artisan products from the region made from sugar cane) also stand out in the sample, with 14% and 12.3%, respectively. For its part, the "other processed foods" classification includes companies that make ice creams, ready mixes for milkshakes, or regional products, such as panela (a product derived from sugar cane used to make beverages) and precooked arepas (snacks made from wheat or corn flour).

The economic activities of the surveyed companies are consistent with the agricultural production of the region, since potatoes, cocoa, coffee, and dairy cattle stand out as the main economic activities of the rural sector of the department of Nariño [83].

The questions included in the survey are presented in Table 5, together with the coding system that is used in Figure 7, which shows a summary and outline of the set of answers of the section about innovation capabilities of companies.

Table 5. Questions about general innovation competencies.

Question	Code
Does your company's strategy take innovation into account and is it considered a key factor for your success?	Key Factor
Does your company have a Research and Development unit? (R&D)?	R&D Unit
Has your company formulated or implemented an innovation strategy? (a formal plan containing objective, actions to carry out, resources, and budget necessary for the development of innovation activities)	Innov. Strat.
Has your company executed technological surveillance studies?	Tech. Surv.
Has your company developed or participated in open innovation processes?	Open Innov.
Does your company have: An Innovation Model, an Innovation Management Model, or an Innovation Management System?	Innov. Mgmt.

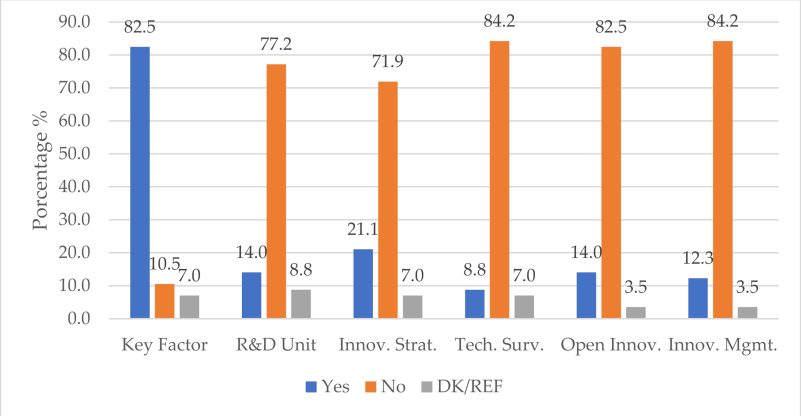


Figure 7. Results of the companies surveyed in relation to their innovation general competencies.

As shown in Figure 7, most of the surveyed companies consider innovation as a key factor for their success (47 companies: 82.5%). However, this item diverges from the rest of the results. In contrast to the first question, only 14% of the companies have an I + D unit, 21.1% have implemented or formulated an innovation strategy, and only 12.3% have an innovation management system or model. Considering the composition of the sample, it is possible that, although many companies understand the importance of innovation in their business models, they do not have the experience or the resources to manage their innovation in a systematic way.

Reference [46] assessed the innovation capabilities of 460 companies from the department of Quindío, Colombia, and reported similar contradictions between the importance that factories say they give to innovation and the investments and strategies that they actually implement in this regard. It should be highlighted that the economy of the department of Nariño depends on the agricultural sector to a great extent. However, this sector paradoxically shows numerous historical barriers, such as scarce technological innovation and lack of horizontal and vertical associativity between the members of the different food chains, which have limited its development and growth [84,85].

The widespread limited innovation capabilities observed in the agri-food sector of Nariño are evident in the analysis of the composition of the surveyed sample of companies, which is made up mostly of young micro-companies. These organizations most likely do not have the financial or technical resources to create a research and development unit or prepare a technology surveillance study. This problem is evident in the answers to the last question of this section about the investments made in research and development. More than half of the surveyed companies do not allocate financial resources for R&D activities, and none of them invest more than 5% of their income on such tasks.

The next section of the questionnaire dealt with open innovation platforms. The results showed that 86% of the studied companies had no knowledge of the concept of open innovation before answering the questionnaire. However, it is interesting that 89.3% of the companies consider that this approach and its application through open innovation

platforms and challenges could be useful for their business models. Even more relevant is the fact that 71.4% of those surveyed companies said that they were willing to implement this type of initiative.

The companies were also surveyed whether they think that the organization would benefit from an outside-in (where knowledge and technologies are searched outside to be applied in the company), inside-out (exporting or commercializing their own internal knowledge, this way helping other companies to solve their problems), or a mixed (a combination of the two previous initiatives) model. Figure 8 illustrates the results.

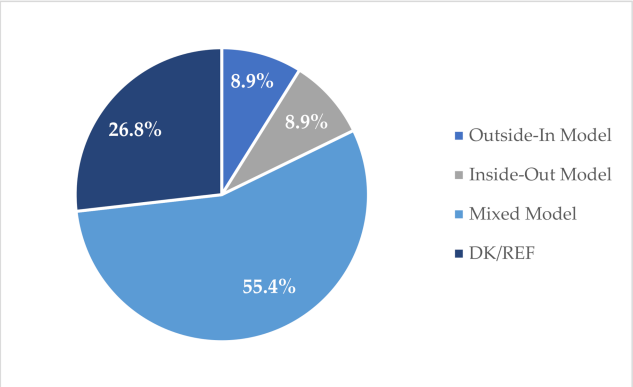


Figure 8. Most likely adoption open innovation approaches among surveyed companies.

As can be seen in Figure 8, most surveyed companies (55.4%) indicate that the most appropriate approach model for their business would be the mixed approach. Furthermore, 8.9% of companies indicated that they believe they could benefit from an inside-out approach. Considering the data presented in Figure 7, it is striking that a large percentage of those surveyed consider that their companies could be good candidates for a mixed or inside-out approach, since most companies have poor innovation capabilities.

Open innovation from the inside-out requires that companies present a solid innovation management structure and the broad integration of multiple technologies that are usually foreign to MSMEs. Therefore, outside in open innovation is the most widely adopted by companies and is also the most studied by academics [86].

This inconsistency can be explained by the fact that most of the surveyed companies had no prior knowledge of the concept of open innovation and its different approaches, in fact, almost 30% of the respondents did not answer this question. However, considering that the sample is mainly made up of young microenterprises and companies that, therefore, may not have the financial resources to innovate in a systematic way, they could greatly benefit from outside-in models, finding external solutions to their various problems and challenges with a lower budget.

- Collaboration with external partners in the innovation process:

Participants were asked about their companies' relationships with five external factors involved in the innovation process: suppliers, buyers, universities (research groups), competitors, and independent experts. Each of these fields were included in an independent section that, in turn, had several questions or items that were answered using the Likert scale from 1 to 5.

Cronbach's alpha coefficient was used to assess the internal validity and reliability of the scales that included several items. The statistical summary of these variables can be found in Table 6, which also shows values of performance and propensity towards innovation of the companies. Here, the same type of scale was used.

Table 6. Statistical summary of validity of variables assessed through a Likert scale.

Variable	Questions	Cronbach's α	Sample Average	Standard Deviation SD
Cooperation with customers	4	0.74	2.82	1.00
Cooperation with suppliers	4	0.89	3.06	1.21
Cooperation with competitors	3	0.85	2.03	1.12
Cooperation with universities	4	0.92	2.03	1.18
Cooperation with independent experts	4	0.87	2.57	1.24
Innovation Performance	6	0.91	2.64	1.16
Innovation Propensity	4	0.92	3.58	1.26

The closer Cronbach's alpha is to 1, the more consistent the items will be with each other. The values of this coefficient for the analyzed variables ranged between 0.74 and 0.92. According to [87], Cronbach's values higher than 0.7 are considered acceptable, while those higher than 0.8 are desirable. Similarly, [44] considered Cronbach's alpha values between 0.60 and 0.92 as acceptable for their study. In the Supplementary Materials section, there is a link to the average response values of all the questions that make up the parameters.

The extent of collaboration of the surveyed companies with all the external actors analyzed is deficient, since average values between 2–3 were obtained in all cases (the scale used ranges from 1 to 5). From this data set, the variable with the highest score was cooperation with suppliers.

On the other hand, the weakest relationships of companies correspond to those established with universities and competitors. The relationship with competitors was similarly the worst rated variable [44], working on a diverse sample of companies in Austria. Indeed, their methodological basis was followed in this section, which considered four additional types of external actors (intermediaries, communities, non-governmental organizations (NGOs), and public institutions). Considering the distrust and uncertainty involved in working hand in hand with direct competitors, this result is understandable. On the contrary, the researchers indicate that collaborations with universities was one of the best valued (3.62 in average), placed only below relationships with customers.

In their research on the degree of openness of small- and medium-sized agro-industrial business in the department of Atlántico, Colombia, [88] indicate that acquisition capacity, geographical proximity to customers and suppliers, signing of contracts, size, and innovation barriers are the significant variables that explain the breadth and depth in the use of external sources to innovate and reveal the need to create environments that encourage the creation of cooperative interorganizational networks to innovate in order to consolidate geographic spaces based on the economy of knowledge. On the other hand, [89] studied the barriers to the use of the open adoption by small- and medium-sized companies in Ghana and stated that the main drawbacks are related to the difficulty in finding suitable partners, cooperation, and coordination problems related to operational functions, lack of flexible internal structures, organizational inertia, and opportunistic or individualistic behavior of the partners.

The average scores for the variables Innovation Performance (6 questions) and Innovation Propensity (4 questions) were 2.64 out of 5 and 3.58 out of 5, respectively.

Thus, answering RQ5, the department of Nariño has specific conditions that were reflected in the composition of the sample of companies that answered the questionnaire. It is a region with a strong agricultural vocation, which is generally expressed in smallholdings. However, despite being generated from quality raw materials, the department's processing industry never developed strongly [84,85,90]. Therefore, there are not many large food companies in the region, which was reflected in the survey. In fact, most of the companies surveyed belong to the so-called micro-companies (less than 10 employees).

This gives the sample different characteristics from most cases studied in the SLR, such as the work of [44] (one of the references in the elaboration of the questionnaire), carried out in Austria and in whose sample almost 92% of the companies had more than 100 employees. This may explain the marked differences between the results of this work

and the study, for example, the mean values for the innovation performance of companies of 2.64 and 3.79, respectively.

The general innovation capabilities of companies are also quite deficient (Figure 7), and the budget for innovation is minimal. However, the responses also reveal that some companies are concerned about maintaining good relations with some of their external partners (mainly with suppliers) and seem to participate in joint innovation processes, despite being unaware of the theoretical concept of open innovation.

In accordance with this, [14] suggest that collaboration processes with suppliers are common in the agri-food industry because incremental innovations tend to emerge from intense relationships established between buyers, suppliers, and other business partners. They point out that small- and medium-sized companies develop this type of alliance, since they do not have sufficient financial, labor, or infrastructure capacities to carry out their own conventional type of closed innovation. A similar diagnosis was reached by [66], who studied a sample of 14 agri-food Vietnamese companies and found that they had no experience with innovation in the development of new products and were not familiar with joint creation. Nevertheless, these companies recognized the need for innovation and were enthusiastic about the co-creation approach.

4.2.2. RQ6: Is There a Positive Correlation Between Open Innovation Practices and the Innovation Performance of Companies in the Agri-Food Sector?

To answer the last research question based on the data collected by the questionnaire, a statistical analysis was performed using Pearson's correlation coefficient and benchmarking approach. Thus, a statistically significant positive correlation between the average innovation performance of the companies and their degree of collaboration with the five analyzed external actors was observed (Pearson > 0.7). This dataset can be seen in Table 7.

Table 7. Pearson's correlations between innovation performance and collaboration with various external partners.

	Innovation Performance	**Customers**	**Suppliers**	**Competitors**	**Universities**	**Ind. Experts**
Innovation	Correlation (r)	0.6479	0.571	0.3736	0.5474	0.6106
Performance	*p*-Value	0.0000	0.0000	0.0064	0.0000	0.0000
Customers	0.6479	Correlation (r)	0.6973	0.5141	0.503	0.6424
	0.0000	*p*-Value	0.0000	0.0001	0.0001	0.0000
Suppliers	0.571	0.6973	Correlation (r)	0.4674	0.5445	0.7076
	0.0000	0.0000	*p*-Value	0.0005	0.0000	0.0000
Competitors	0.3736	0.5141	0.4674	Correlation (r)	0.5482	0.6124
	0.0064	0.0001	0.0005	*p*-Value	0.0000	0.0000
Universities	0.5474	0.503	0.5445	0.5482	Correlation (r)	0.7007
	0.0000	0.0001	0.0000	0.0000	*p*-Value	0.0000
Independent	0.6106	0.6424	0.7076	0.6124	0.7007	Correlation (r)
Experts	0.0000	0.0000	0.0000	0.0000	0.0000	*p*-Value

Note: r = Pearson's correlation coefficient. r > 0 indicates a positive correlation. Values of $p < 0.01$ indicate that the correlation is statistically significant, with a confidence level of 99%.

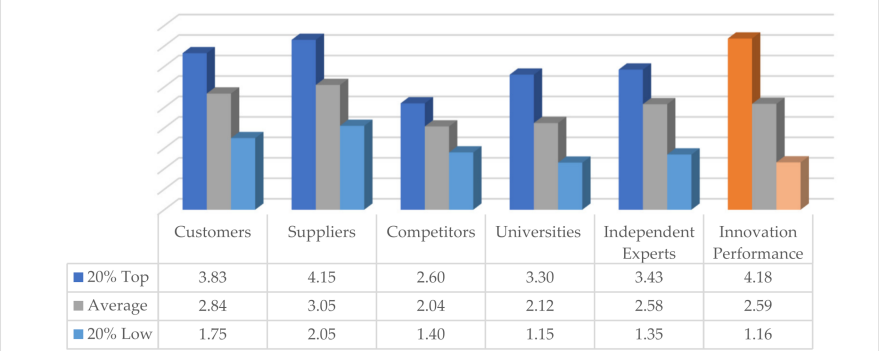
The strongest correlation of innovation performance was established with collaboration with customers (r = 0.6479. $p = 0.0000$), whereas the correlation with collaboration with competitors was the weakest (r = 0.3736. $p = 0.0064$)). The more marked correlation allows us to infer that cooperation with customers may be more profitable and fruitful for the innovation performance of companies than their relationships with competitors. However, joint innovation between competitors was scarce in most of the companies surveyed, which may be due to the trust problems present in this type of association.

In addition, reference [44] reported similar results, finding positive and significant correlations between economic performance in innovation and collaborations with three (customers, universities, and NGOs) of the nine external partners that where assessed, in which collaborations with customers (r = 0.33; $p < 0.001$) was the strongest correlation.

Traditionally, agri-food companies pursue ever closer relationships with their customers to better understand their expectations and needs. According to [67], this path often leads to co-creation, which is supported by customer engagement and uses their feedback to improve product development. This process requires the participation of customers in studies aimed at understanding the impact and performance of the product. [63] states that product innovation promotes short- and long-term growth, since it attracts customers and satisfies existing customers.

The correlations revealed in this study were complemented by applying a benchmarking approach. This is a commonly used procedure that identifies successful factors, so it is considered an appropriate method to explore what better-performing companies do differently in comparison to their less successful peers. Therefore, benchmarking is used to identify factors (e.g., open innovation management practices) that could be responsible for achieving superior results over competitors [44].

In this case, the companies that left blank answers in the questionnaire were omitted, since inconsistencies in the average values could be generated due to lack of information. Thus, the sample considered for the benchmarking approach was 52 companies. As can be seen in Figure 9, the top reference group for the analysis corresponded to companies in 20% of the upper quartile (10 companies), with respect to the average values of the composite variable Performance in Innovation.



	Customers	Suppliers	Competitors	Universities	Independent Experts	Innovation Performance
20% Top	3.83	4.15	2.60	3.30	3.43	4.18
Average	2.84	3.05	2.04	2.12	2.58	2.59
20% Low	1.75	2.05	1.40	1.15	1.35	1.16

Figure 9. Comparative study of companies with the best and worst results.

It is evident that, compared to companies with the worst performance, those with better innovation performance also establish fruitful relationships with each of the analyzed external partners, which is corroborated by the results from the Pearson's correlation analysis. The largest gap between the best and worst performing companies was observed in the collaboration with universities item ($\Delta = 2.15$), while collaboration with competitors showed the smallest gap ($\Delta = 1.20$), although the best performing companies developed better relationships with these actors.

According to [12], interactions with academia throughout the innovation process has potential benefits for the actors involved in the productive chains as they constitute a key mechanism in generating impacts, which can be observed in the diversity of products resulting from new knowledge, methods, technologies, training modules, and experimental networks. They also suggest that the way in which the interactions between researchers and other innovation actors are structured is a decisive factor in shaping the impact pathway outlined by the research endeavor.

4.2.3. Effects of Covid-19 Pandemic

In this section, and based on seven different aspects, participants were asked about the effect that the new coronavirus pandemic has had on their companies. A Likert scale, ranging from −3 to 3 (from highly negative to highly positive effects), was used, which also included a null affectation (0). The variables considered and their statistical values are summarized in Table 8. The average number of surveyed companies state that the pandemic negatively affected their business in all the previously assessed variables, with

innovation budget being the most affected. Indeed, 41 companies experienced negative effects on their innovation budget because of the pandemic and 55.4% of the sample reported a strong negative impact in this regard (a score of −3).

Table 8. Effects of the COVID-19 pandemic on the surveyed companies.

Variable	Average	SD (s)
Innovation budget	−1.87	1.63
Innovation capabilities	−1.42	1.81
Relationship with customers	−1.21	2.06
Relationship with suppliers	−0.92	1.98
Closing or opening of new markets	−1.23	2.07
Participation in innovation challenges	−1.19	1.68
General performance of the company	−1.36	1.74

Note: A Likert scale from −3 (highly negative effects) to 3 (highly positive effects) was used.

Similar results were obtained when participants were asked about the affects they foresaw in a year on their companies because of the pandemic. However, the magnitude of the expected effect was less than or equal to all the studied factors. In both cases, participants thought that their relationship with suppliers would be the least affected.

5. Discussion

Based on a Systematic Literature Review and the application of a structured survey, this article made it possible to compile the trends, benefits, and challenges that open innovation poses to the agri-food sector.

The SLR approach was used to deeply analyze 50 recent articles published in Q1 and Q2 journals. As a result, the most influential and representative countries and researchers, in terms of open innovation studies focused on the agri-food sector, were identified.

The results reveal a clear leadership of European countries regarding the number of publications in higher impact journals, with Italy, the Netherlands, and Spain in the top positions. The clear dominance of European countries, mainly Western Europe, regarding high-impact publications in this field is not surprising. The existence of traditional research centers in agribusiness, countries that are world leaders in agricultural innovation, such as the Netherlands, and technology transfer models that efficiently connect academia with companies in the sector give the old continent a vast advantage over other nations [70,75].

Studies with similar approaches, such as [6], coincide in this assessment. In their review work on open innovation in the agri-food chain, among 45 articles published between 2006 and 2015, European authors represented 90% of the selection.

A comprehensive literature review on general open innovation, which included 1046 articles published between 2003 and 2017 in 318 journals (Social Sciences Citation Index–SSCI) [22], revealed that Europe was the most productive continent, highlighting the notable increase in publications from Italy in recent years. However, this report ranked the United States in first position, with the largest number of articles published, showing that the North American nation, where the concept of open innovation first emerged, continues to be a focal point for related research; however, the agri-food sector does not seem to be a topic of greater interest in these studies.

Likewise, the main trends, application subsectors, and prominent challenges in studies that are being carried out within the sector were presented. The most promising study focuses on open innovation within the agri-food systems that correspond to development of new products: co-creation, bioeconomy, and eco-innovations.

The last two topics show that the current situation in the agri-food sector is not alien to global trends in favor of cleaner economics and green technologies. It is also evidenced that companies can be greatly benefited in this regard by working together with the other links in their production chain and, therefore, by approaches such as open innovation.

Regarding the structured survey, there was a sample of 57 companies from the department (state) of Nariño. The surveyed companies (mostly micro and young companies)

presented, on average, poor innovation capacities and reported low investments in this regard. However, most reported considering innovation as a key factor in business success and said they were interested in participating in open innovation processes.

The foregoing allows us to infer that the limited innovation capacities of the sample are more related to economic barriers than disinterest or lack of will. In this sense, the agri-food sector in the region could greatly benefit from the adoption of open innovation models that allow companies to have access to external solutions to their innovation challenges. An outside-in model of open innovation seems to be the most promising for these types of companies.

It is especially advisable to narrow the support channels between the universities and the business sector, since the associations with this type of institutes were among the weakest, according to the responses to the survey. Studies such [45] suggest that universities are one of the most solid sources of external knowledge, showing a positive correlation between active collaboration with universities and technological innovation of the company, in addition to relationships with the future direction of the company's market and the development of new products. Other research [9] reveals the role of academia in the processes of technological scaling of relationships with the competitiveness of various industries.

Furthermore, a section that was useful for determining the impact experienced by companies because of the new coronavirus SARS-CoV-2 pandemic was incorporated in the study. As might be expected, most companies have seen their innovation capabilities hurt because of the global health crisis. The questionnaire used (see Appendix A) may be useful for future research aimed at establishing the level of openness and collaboration of agri-food companies or those operating in different economic sectors with external actors.

6. Conclusions

Open innovation, seen as a competitiveness strategy, is rapidly expanding among agri-food companies. Comprehensive literary reviews that compile empirical information and findings in different regions and subsectors are necessary to clarify the new paradigms with the specific challenges and opportunities in this sector.

Through a systematic literature review and a structured survey, this work allowed us to highlight potential opportunities offered by open innovation to micro, small- and medium-sized companies, particularly those related to better technology transfer processes and reduction of infrastructure and logistic costs derived from traditional innovation models; however, companies need an adequate innovation management system to get the most out of cooperative relationships with external partners.

The main challenges within the agri-food sector for this approach are related to the lack of government support, obsolete and poorly standardized regulations for the management of intellectual property, and communication barriers between involved parties.

The organization and application of a structured survey to a sample of 57 small- and medium-sized agri-food companies from Nariño, Colombia, was useful for the discovery of a clear positive correlation (Pearson) between two items: collaboration with various external actors and innovation performance of companies.

As a general conclusion, open innovation has multiple potential benefits for the competitiveness of companies. Additionally, it can promote a better cohesion and technological development in the agri-food systems and between all actors that are included.

Supplementary Materials: Complementary data to the results of the structured survey as the average values of all the items that make up the variables can be found in: https://www.mdpi.com/article/10.3390/joitmc7020161/s1.

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Appendix A

Questionnaire used for the structured survey (Based on the methodologies from [44–46]).

1. Basic Data: Email address
   Company name
   Name of the person who answers this survey (NOT required)
   Position held in the company.
   Municipality
   Age of the company:
   - 1–3 years
   - 3–7 years
   - 7–12 years
   - 12–20 years
   - more than 20 years

   Company size (direct jobs):
   - 10 or fewer workers
   - between 11 and 50 workers
   - between 51 and 100 workers
   - between 100 and 250 workers
   - more than 250 workers

   At what level (s) of the food chain does the company operate?
   - Production (agriculture, livestock, fishing)
   - Processing and transformation (industry)
   - Sales/Marketing

   Note: Please watch the following video before answering the questions: https://www.youtube.com/watch?v=LlrUVde69VI&feature=emb_title&ab_channel=JhonWilderZarthaSossa (accessed on 28 June 2020).

2. General Innovation Skills
   - 2.1 Does your company's strategy take innovation into account and consider it a key factor for its success? (Yes/No/DK-REF)
   - 2.2 Does your company have a Research and Development Unit (R + D or R + D + i)? (Yes/No/Don't know or Refuse to answer)
   - 2.3 Has your company formulated or implemented an innovation strategy? (formal plan where the objectives, the actions to be carried out, the resources, and the budget necessary for the development of the innovation activities are defined) (Yes/No/DK-REF)
   - 2.4 Has your company carried out technological surveillance studies? (Yes/No/DK-REF)

2.5 Has your company developed or participated in open innovation processes? (Yes/No/DK-REF)
2.6 Does your company have an Innovation Model, Innovation Management Model, or Innovation Management System? (Yes/No/DK-REF)
2.7 The expenditure that the company allocates to research and development activities corresponds approximately to:

- 0% of the total turnover (income) of the company
- 1–2% of the total turnover of the company
- 2–5% of the total turnover of the company
- More than 5% of the total turnover of the company
- DK-REF

3. Platforms and Open Innovation Challenges

3.1 Did you previously know the open innovation concept/system? (Yes/No/DK-REF)
3.2 Do you know or have you heard of any of the following open innovation platforms?

- SUNN (before watching the video)
- Innocentive
- Ninesigma
- Moonshot
- Ocean
- Yet2
- DK/REF (do not know/Refuse)
- another...

3.3 After watching the video, do you think the platforms and leftovers of open innovation could be useful in your company's business model? (Yes/No/DK-REF)
3.4 After watching the video, would you consider linking your company to open innovation platforms to find solutions to your internal problems or challenges? (Yes/No/DK-REF)
3.5 If you consider linking your company to open innovation platforms, do you think it would benefit more with an outside-in model (looking for knowledge and technologies abroad to apply it in your business), and inside-out model (exporting (commercializing) its own internal knowledge, thus helping other companies to solve their problems), or a mixed model (combining the two previous models)?

- Outside-In Model
- Inside-Out Model
- Mixed Model
- DK/REF

For each of the following cases, please rate how much the statement agrees with the current situation in your company on a scale of 1 to 5, 5 being TOTALLY ACCORDING TO THE COMPANY'S SITUATION and 1 being TOTALLY DIFFERENT TO THE CURRENT SITUATION OF THE COMPANY.

4. Collaboration with External Partners in the Innovation Process: Customer Participation

4.1 We maintain regular communication with our clients to incorporate the information provided directly into our production processes (1-5-DK/REF).
4.2 We involve our clients directly in the innovation process (1-5-DK/REF).
4.3 We have effective relationships with our clients that allow us to implement better solutions to their needs using the most appropriate technology (1-5-DK/REF).
4.4 We regularly conduct market research (e.g., surveys, target group analysis, etc.) to obtain more information about our clients (current and potential) (1-5-DK/REF).

5. Collaboration with External Partners in the Innovation Process: Supplier Participation

5.1 We maintain regular communication with our suppliers to obtain in-depth knowledge about their ongoing technological developments (1-5-DK/REF).
5.2 We actively involve our suppliers in the process of developing new products or improving processes (1-5-DK/REF).
5.3 Our suppliers play an important role in our product development activities and/or operational processes (1-5-DK/REF).
5.4 We encourage cooperation in Research and Development (R&D) with our suppliers to configure our activities of product development, process improvement, or technology acquisition more effectively (1-5-DK/REF).

6. Collaboration with External Partners in the Innovation Process: Participation of Competitors
   6.1 Within the development of new products or technological improvements, we align ourselves with selected competitors to accelerate development processes and share costs (1-5-DK/REF).
   6.2 We carry out R&D cooperation with competitors to take advantage of synergies, if they are not key or sensitive knowledge (1-5-DK/REF).
   6.3 We exchange information with competitors and reach benchmarks with them to stay up to date with the latest technological developments and trends (1-5-DK/REF).
7. Collaboration with External Partners in the Innovation Process: Participation of Universities
   7.1 We maintain constant R&D cooperation with universities to jointly develop new technologies and new products and/or to improve our productive, logistical, or organizational processes (1-5-DK/REF).
   7.2 We maintain regular communication with universities to always be up to date with the latest technological inventions related to our business (1-5-DK/REF).
   7.3 In case we experience technological problems related to product development processes or our operational logistics, we usually work closely with universities to find solutions (1-5-DK/REF).
   7.4 The regular exchange of information with universities and the technology transfer process are important to our firm (1-5-DK/REF).
8. Collaboration with External Partners in the Innovation Process: Participation of Independent Experts
   8.1 We work together with independent experts (e.g., public research institutes, engineering consultants, companies specializing in technology, etc.) in terms of contractual agreements to solve technological problems within the development processes of new products and/or operational or logistical processes (1-5-DK/REF).
   8.2 We regularly contact independent experts in the innovation process (products, processes, organizational improvements) (1-5-DK/REF).
   8.3 In the context of new product development processes, we work with institutions (e.g., public research institutes, engineering consultants, specialist companies, etc.) and people with special knowledge to take advantage of their ideas (1-5-DK/REF).
   8.4 Regular knowledge exchange with independent experts is important to our company (1-5-DK/REF).
9. Performance Measurement: Performance in Innovation
   9.1 We bring new and innovative products to the market or implement new operational or organizational processes more frequently than other companies in the sector (1-5-DK/REF).
   9.2 In our market, we are known for our innovative products and processes (1-5-DK/REF).
   9.3 Our new products differ substantially from their predecessors.
   9.4 The percentage of new and innovative products in the product portfolio is significantly higher compared to our competitors (1-5-DK/REF).

9.5 We open new markets more frequently than our competitors (1-5-DK/REF).
9.6 The percentage of sales generated through new and innovative products is significantly higher compared to our competitors (our new products are better received) (1-5-DK/REF).

10. Performance Measurement: Propension to Innovation
    10.1 When was the last time the company incorporated a new technology into its core business?
    - Less than 1 year ago
    - Between 1 and 2 years
    - Between 2 and 3 years
    - Between 3 and 5 years
    - More than 5 years ago.
    - DK/REF

    10.2 When was the last time the company started selling a new product?
    - Less than 1 year ago
    - Between 1 and 2 years
    - Between 2 and 3 years
    - Between 3 and 5 years
    - More than 5 years ago.
    - DK/REF

    10.3 When was the last time the company changed its organizational structure? Less than 1 year ago
    - Less than 1 year ago
    - Between 1 and 2 years
    - Between 2 and 3 years
    - Between 3 and 5 years
    - More than 5 years ago.
    - DK/REF

    10.4 When was the last time the company changed its distribution or marketing channels?
    - Less than 1 year ago
    - Less than 1 year ago
    - between 1 and 2 years
    - between 2 and 3 years
    - between 3 and 5 years
    - More than 5 years ago.
    - DK/REF

11. Effects of the Pandemic (Covid-19) on Innovation The global emergency due to the Covid-19 virus has affected all sectors of the economy to a greater or lesser extent. Please answer the following questions to find out its repercussions in the agri-food sector.
    11.1 How has the pandemic affected your company in the following aspects? (Scale between -3 (very negative effect), 0 (no effect) and 3 (very positive effect)):
    - Budget for Innovation
    - Innovation Capabilities
    - Customer relations
    - Relationship with suppliers
    - Closing or opening of new markets
    - Participation in innovation challenges
    - General performance of the company

11.2 How do you think the pandemic will have affected your company in a ONE YEAR horizon? (Scale between −3 (very negative effect), 0 (no effect) and 3 (very positive effect)):

- Budget for Innovation
- Innovation Capabilities
- Customer relations
- Relationship with suppliers
- Closing or opening of new markets
- Participation in innovation challenges
- General performance of the company

11.3 How do you consider that the pandemic may affect the following processes in the agri-food sector of Nariño?)Scale between −3 (very negative effect), 0 (no effect) and 3 (very positive effect)):

- Generation of new technologies
- Technology transfer
- Absorption of new technologies
- Adaptation of new technologies
- Diffusion of new technologies

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Article

Sensing Technologies, Roles and Technology Adoption Strategies for Digital Transformation of Grape Harvesting in SME Wineries

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Abstract: The article improves understanding on leveraging new technology for DT (digital transformation) of grape harvest in SME wineries. It provides evidence on technologies used and workplace types deployed in grape harvesting, as well as strategic paths in deploying new technology, thereby contributing to the literature on networked sensing and seizing capabilities in the wine industry 4.0. The research approach is explorative and qualitative drawing on 31 interviews with wine industry 4.0 experts and managers, mostly owners of SMEs: wineries, wine software and wine machinery enterprises. Resulting findings serve as a roadmap for digital transformation of grape harvest process in SME wineries explaining technologies and work roles necessary for DWT (digital workplace transformation), as well as strategic paths of deployment of novel grape harvest technology. Previous research on the wine industry 4.0 has focused on BMI, while this research expands the focus to include a wider concept of technology adoption strategy as well as DWT. The research identifies two types of factors impacting the strategic deployment of grape harvest technology: pull factors, also termed servitization factors, as well as push factors, termed also digital transformation factors.

Keywords: industry 4.0; DWT-digital work transformation; servitization; networked innovation; SME innovation; push-pull strategies; family business

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1. Introduction

The study at hand provides an evidence-based sensing and technological forecasting roadmap to the field of the wine industry by deploying open innovation between different actors involved. Having in mind that no previous research has dealt with the changes in work roles and new technology adoption strategies for the wine industry 4.0, this article closes this research gap. Relevant practice-oriented implications for networked, open innovation of grape harvesting as well as theoretical contributions to the emerging field of open innovation in SMEs are delivered.

The paths to the digital transformation of firms are numerous, as are the theoretical approaches and practical tools available to navigate this change. One of the more notable theoretical approaches to digital transformation of firms is that of dynamic capabilities, which are essential for digital transformation: (1) digital sensing capabilities (filtering and evaluating digital opportunities), (2) digital seizing capabilities (prototyping and defining business model (BM) value proposition) and (3) digital transforming capabilities (governing and aligning assets in accordance with innovation ecosystem) [1–3]. Sensing and seizing, have also been identified as key activities related to open innovation of local innovation ecosystems, which precedes the transformation of the businesses [1]. Having this theoretical framework in mind, this study deals with collaborative sensing and seizing activity of relevant actors in a low-tech wine production ecosystem regarding future change

of the grape harvesting logistics in wine production SMEs. Logistical ecosystems and the potential use of digital platforms are identified to be one of the most promising future venues for digital ecosystem research [4]. The wine industry is an agricultural industry and is therefore considered to rather belong to low-tech and highly networked industry, where the implementation of new digital technologies for productivity growth is usually lagging behind other industries [5–9]. However, digital transformation of all processes is identified as an inevitable process of transition [10]. In order to research the collaborative efforts of SMEs towards transformation of grape harvesting logistics in the wine production ecosystem, two research questions have been created:

RQ1: What is the current state of the grape harvesting process among networked SMEs in a low-tech wine industry, regarding technologies used as well as work roles involved?
RQ2: What are possible digital transformation pathways of networked SMEs on the example of grape harvesting for wine production?

Open innovation is an innovation path which focuses on external sources and inbound paths of innovation towards the organization [11]. Open innovation is relevant for all the aforementioned research questions, because the higher the number of actors and the more diverse they are, the more they can benefit from tearing down knowledge barriers through collaboration [12–14]. There are, however, limitations to firms benefiting from open innovation which relate to firms capacity to absorb innovations as well as strategic focus of external cooperation [15]. Therefore, the research questions are based in open innovation as a research approach by considering both the demand pull of SME wineries as customers of wine hardware and software producers, as well as DT push, related to the new technologies being developed and offered inside industry 4.0. They are two basic strategic paths of technology adoption.

The workplace seems to be one of the central elements of open innovation, where compassion is important not only for fighting uncivil behavior, but more importantly for supporting organizational culture with open innovation at its core [16]. In order to understand the nature and scope of DT of grape harvesting, existing technologies and work roles need to be identified so as to understand the scope of changes for skilling and reskilling the workforce inside open innovation. Developing the right digital skills at the regional level appears to be the key to successful DT efforts [13].

Having this research framework in mind, the present research provides evidence regarding opportunities (sensing) for changing technologies and work positions (roles) for grape harvesting. It also maps major factors influencing organizational change strategies (seizing) around grape harvest innovation. In the discussion, it provides an outlook on the possibilities for governing and aligning assets inside wine SME network. This is especially important having in mind that presently no institutional arrangements exist for common, networked digital transformation of the researched SMEs, although they are located in several neighboring wine regions in Germany. The regions include the Mosel-Saar-Ruwer, Rheingau, Nahe, Rheinhessen, Palatinate and Hessische Bergstrasse.

It is important to notice that, digital transformation does not rely only on digital transformation capabilities, but is preceded by digital sensing and digital seizing. The digital transformation path of organizations also largely depends on the level of digitalization of the industries in which the company operates, and of the innovation ecosystems it takes part in. Organizations belonging to traditional industries, can be classified as traditional or pre-digital as opposed to born-digital organizations which developed from high-tech startups [17,18]. The pre-digital organizations are in clear need of catching-up in terms of new technology, but there is a research gap on how these processes happen in a networked industry setting, where born-digital organizations offer their services to traditional pre-digital organizations, while other pre-digital actors are well underway with their digitalization strategies? The wine industry is therefore a suitable pre-digital industry for observing these phenomena.

Having in mind the ever-increasing digitization of all societal processes from analog to digital, the digitalization is an inevitable transformative force shaping the way people

interact, communicate, model their business and generate revenue [19–22]. In recent years, digital transformation in SME's has been spurred by the industrial revolution 4.0 with the abundance of new technological opportunities [23,24]. Digital transformation should be a process of strategic value for SMEs, taking one of three basic trajectories: (1) customer value proposition, (2) operating model, (3) simultaneous transforming of customer value proposition and operating model [25]. Innovating the operating model is usually driven by technology push, while innovating customer value proposition is usually driven by demand pull, thereby forming two most important innovation trajectories [26]. An important aspect of innovating operating model is the question of the future workforce needs. New ICT technologies are blurring market boundaries and consequently disrupt roles of different actors while some actors are even deemed unnecessary- co-creation with customers, co-opetition with competitors [22]. The consequences of digital transformation on work have both positive (less routine work, more flexibility in place and time) as well as negative aspects (24 h online burnout, unsecure and underpaid freelance status, de-professionalization and substitution of certain jobs such are journalists, para-legals, educators and sommeliers) [27]. Therefore, digital workplace is and under-researched field with ample opportunities for new value creation, by disrupting the existing workplaces and creating new, digital ones [28].

Innovating in a strategic way is important for optimally deploying available technologies and radically transforming both overall sustainability as well as economic performance [29]. In this sense, new technologies need to be defined through business models, as key levers for understanding and effectively communicating competitive strategies [30]. SMEs in commercial settings seem to prioritize technologies which can contribute to overall SME results in a quick, tangible fashion, in order to manage the risk associated with innovation adoption [31]. While undergoing digital transformation, company shouldn't lose sight of their core objectives, which follow from the profit logic, and are based in the clearly identifiable and profitable target market [32,33].

Firstly, the existing knowledge on the changing nature of the work in relation to changing technological landscape inside digital transformation is presented. This review of existing knowledge covers technology adoption strategies in SMEs as well as the specificities of networked innovation in SMEs. Following, the qualitative research method deployed in this study is presented and discussed in detail, as well geographical distribution and positions of interviewees. The results section starts by the technologies deployed as well as work roles involved, along with the most interesting verbatim citations for both categories. Then, a unified framework on opportunities for digital transformation of grape harvest process is being presented. The second part of the results deals with pull strategies and push strategies of technology adoption, firstly by presenting the underlying verbatim citations, and then by presenting a unified theoretical framework of wine SMEs grape harvest technology adoption strategies. The discussion deals with the contribution of the findings to the human, technological and organizational literature on redefining the future of work as well as digital transformation of SMEs. The contributions are than discussed regarding the SME network aspects of the present research methodology. Results summarize both the theoretical contributions of the research as well as practical implications for furthering DT in the wine industry and creating the wine industry 4.0.

2. Literature Review

2.1. Work in the Age of Digital Transformation

Managers need to be aware of the different strategies for workforce training and associated costs (through rate of forgetting, technology depreciation and advancement) when considering the technology upgrade decision [34]. Having in mind the complexity involved in such investments, the phenomenon has been termed digital workplace transformation (DWT) in the literature. DWT includes several important dimensions which should be considered: physical space, culture, social system and technology [35]. At the level of the individual workers inside DWT, support needs to be provided in realigning and managing

their non-work identities with their work identity, as well as balancing between regular and dynamic routines [36,37]. Therefore, the use of digital technologies in the workplace should be designed to promote mindfulness, empower workforce through participation and alter leadership culture in order to reduce technostress and promote compliance [38–40]. Furthermore, workers should feel and effectively be enabled to be autonomous, competent and connected in order to support their performance and well-being [41,42]. Some authors classify DWT as a non-technological field of innovation, but nevertheless acknowledge its crucial importance for digitalization and acceleration of technological developments as well as industry-level competitiveness [40].

Creating digital workplace is not about emails and social media, nor is it about integrating digital technologies- it is about transforming personal, team and organizational performance [43–45]. This process of change includes also the process of deinstitutionalizing the entrenched workplace practices by deliberately delegitimizing and abandoning them [46]. A modern workplace should get rid of rigid rules and instead empower employee participation and networking through value-based guidelines—this provides the basis for an increasing workforce maturity, and consequently business innovation and growth [3,25]. However, this process is not straightforward nor is it without perils. Crafting a digital workplace in pre-digital organizations presents a disruptive process for what was previously approached as long-term information system planning [17]. In addition, the labor practices of new app-based platforms have sparked litigations around whether work provided through a platform constitutes employee status or not [47]. It has become a common place for all organizations to outsource activities relating to IT and software development to external companies, thereby creating different work positions with different skillsets sought for in non-IT companies (more technical skills) and IT companies (more business and project management skills) [48].

2.2. Technology Adoption Strategies in SMEs

Technology is a construct that goes beyond engineering and manufacturing only, to include the whole process of transforming production inputs (labor, capital, material, information) into production outputs (products, services) [29,49]. Technology adoption strategies are directly connected to the issues of business model transformation, as well as the interplay between path dependence, strategic flexibility and a number of business modules involved [24,50,51]. The business-level perspective of technology adoption inside industry 4.0 recognizes that the redesign of operating processes is an important element of this transitioning process which can take different pathways, from being dominated by demand pull (high servitization level), to being dominated by technology push (high DT level) [24,26]. This is why the present research orders the adoptions strategy factors into these two major groups—servitization challenges and digital transformation opportunities. The previous literature has recognized the need for industrial BMs to transition to solutions-based BMs [52], which is of particular relevance for industrial SMEs in the wine industry. This integrated, solution-based BM balances between the front-end push and back-end pull for delivering value to the customers [53].

Having in mind that a large proportion of SMEs in the researched wine industry are family owned, this factor is very important for understanding the adoption of new technology. Previous research has confirmed that the approach to technology adoption in SMEs depends also on the digital leadership style of the SME owners as well as on the impact a family has in the company [54]. Family influence is proven to negatively influence the pace of technology adoption in SMEs, especially if they are minority, rather than majority owners [55]. However, it has been proven that family influence has an impact only on the later identification of discontinuous change, while the implementation, once initiated, is being conducted more quickly and with more stamina [56]. SME wineries seem to be reluctant to adopt sustainability innovations which bring only environmental and social benefits, with no tangible economic or commercial benefits [57,58].

2.3. Networked Innovation in SMEs

The knowledge-based interdependence of SMEs is often termed coopetition (consisting both of cooperation as well as of competition) and motivates entrepreneurs to participate in innovation processes by boosting their network reputation and increasing cooperation with suppliers and consumers [59]. There are three major types of relationship coordination mechanisms inside SME networks: (1) market, (2) hierarchy, (3) social relations, which points to the fact that agents inside networks exchange knowledge even if no market or hierarchy is present, which is also called open innovation [60]. Having this in mind, many organizations are deliberately building open structures and systems which remain in a dynamic, spontaneous and multi-directional relation with the environment [61]. However, SME networks also need suitable governance models, in order to discourage participants from exiting or defecting and to manage the knowledge-based interdependence of firms in a common innovation process [62]. Therefore, researching innovation on the network configuration level is an important strategic instrument for increasing innovation performance and competitive advantage in open innovation approach [63]. SMEs have different strategies when interacting with the SME network both regarding network adaptation as well as external resource dependence [64]. However, it should be noted that for each set of network characteristics, a certain combination of organizational characteristics (goal complementarity, resource complementarity, fairness trust, reliability trust, and network position or embeddedness) correlates with superior performance [65,66]. This research does not deal with the SME network level phenomena directly. However, it takes an explorative, networked methodological approach, thereby providing relevant implications for different actors in a wine industry SME network, ranging from producers of experimental and commercial machinery and software to SME wineries. The results point to the complexity of the researched phenomena, thereby calling for a networked approach to DT and DWT in grape harvesting.

3. Methodology

Semi-structured telephone interviews have been deployed as a primary data collection method. Thirty-one interviews with SME winery CEOs, quality managers, R&D officers, owners and a professor have been conducted in total. All of the companies involved fulfill official requirements for an SME, as defined by the EU: less than 250 employees [67]. Other financial indicators have not been taken into detailed consideration. Another specificity of wine industry is the existence of cooperatives, which are a coordinated network of small grape producers with one big winery dealing with wine making and selling. Some of the respondents were also cooperatives. Sampling has focused on selecting interviewees that were either involved in the grape harvest process (twenty SME wineries), or were providers of commercial technology for grape harvest (five software companies and three harvester and/or cellar technology producers). One interview partner is both a winery owner and a is running a wine software company, one runs experimental wine software development at a university and one is a professor of robotics and geoinformatics in wine industry. Twenty-nine of the interview partners were located predominantly in the state of Rheinland-Pfalz (RLP) and two in the bordering region of Hessen, with links to the wine industry in RLP. This approach provided a network perspective across the state-level value chain. The sampling of data sources was expanded iteratively, allowing the emerging theory and the saturation of our knowledge of subject areas and practices to guide data collection. The data has been analyzed through MaxQDA by engaging in open coding in the first step, and then developing second order themes in connection with the aggregate theoretical concepts. The verbatim citations are presented in Tables 1–3, while the whole theoretical construct with underlying second order codes and connection to first order codes are presented in Figures 1 and 2. Additional tables presenting the first-order codes of push and pull strategies, along with their detailed descriptions and the underlying motivations, have been presented in the Appendices A and B. The two separate questionnaires (one for wine

producers and another one for software and hardware producers) used for conducting the semi-structured interviews are presented in the Appendix C, at the end of the article.

Table 1. Verbatim codes for types of new technologies deployed in SMEs.

Grape berry/must assessment	Inf. 28	*"Take a look at Bordeaux, they go and bite the kernels to check whether they taste bitter, woody or green. Sensory tests are essential! I think the consciousness of physiological maturity receives more attention in other countries* (than in Germany)."
Multi-year field data collection in a database	Inf. 24	*"We work in an Informix database . . . and the historical values of our company go back to the mid 80's . . . We are not in the cloud, the database is located in clients' servers . . . reverse tracking is important . . . this data is being backtracked by vintners themselves . . . our software makes that possible . . . the vintner can trace every wine to its creation, every processing step that he made, every substance that he had added, he can document, even above the wine law requirements. This infrastructure is available and is also used, at least partially."*
Fieldwork logistics and visualisation of processes	Inf. 12	*"A tremendous relief of the working day is useable information, no matter where one is located. I notice this now, that I can access my whole cellar book from my phone: as if I am standing on the tank and saying "how is the tank doing"?"*
	Inf. 16	*"If I optimize the interface and identify on the tablet that "he is there" or "this is going on there", and have that on the PC or on the screen, I have less stress. This is because I can than identify certain risks better. I have less tension and get a better picture; this is very important . . . We are three managers, and there is some degree of exchange between us, but we still need to know what's going on and plan accordingly. The important part of a day is that certain data and facts are being updated quickly."*
	Inf. 29	*" . . . our dream would be to visualize all our vineyards. It allows to visualize both the locations of my customers* (B2B), *my suppliers, as well as vineyards. A further dream would be to have must weight, acidity and rot-affected areas, so harvesting can be directed precisely."*

Table 2. Verbatim codes for challenges fueling the pull, servitization strategies of wine SMEs.

Management assistance	Inf. 16	*"The sensors are from company X . . . It costs money, no question, but the choice is between money and safety. And if I have safety, then I can work better with my people and my customers and not have that much stress. Especially in the harvesting phase, it's about avoiding stress and that's what we have to get rid of. We have to relieve the strain of the manager, that's what we need to do."*
	Inf. 30	*" . . . we had a lot of winery successions* (regarding wineries as customers of software producers) *and the people are just better educated, have different vision of running a winery, and this is an absolute plus point. The market is growing for these technologies and when I project this into the future, from monitoring of vegetation processes in the field to sales, everything will be one digitalized track that monitors all these processes."*
Fieldwork/cellar assistance	Inf. 6	*"I have to take a look at the spot how ripe the grapes are. We have Excel sheets where we write down what we want to do and this is than verified every day to check for changes."*
	Inf. 6	*"All possible* (communication) *options are present, from Email, WhatsApp, Phone and personal contact, depending on the situation. If it concerns everybody, then it is posted to WhatsApp group and when it is about instructions to the fieldworkers, then it is one on one."*
	Inf. 21	*"It is very important for us to see the progress of the work. During the last harvest, a voluminous harvest, it was very important to us to see how well did we progress and how much surface from which grape variety have we processed and how much is still left to be done. Also, regarding how much we are allowed to harvest: do we have to leave it as it is or how are we going to divide it? These are the things that one otherwise does more through gut instinct and rough estimates, and here it is pretty precise . . . It is about dividing the workforce and estimating how long do we still need with how much workforce."*
Gaining competitive advantage	Inf. 7	*"We are committed to innovation and plan accordingly. We have dealt with it intensively, we also have a conversation tomorrow, the grape selection plant, optical sorting. The cost pressure drives this decision. I think people cost us too much money. 15 people do a lot of work and I think this people management is a huge problem, also because I cannot get any German workers. So that means I have to do the work, but without workers. This will be a solution that will be faster, but I don't think it will be better."*
	Inf. 24	*"The more ambitious they* (the wineries) *are, and the higher the quality they produce, the more they ask for such quality-optimizing options: to select as soon as possible, what will I get when and whom do I assign the order. The Pino Gris- I don't need 14.5% as in the 2018 harvest. I would like 13.5% alcohol, so it is easily digestible, with higher acidity,* etc. *These are the elements that are interesting for quality and are of interest for many users, because there is an added value behind this that is reflected in the quality and thus in the revenues."*

Table 3. Verbatim codes for company opportunities, fueling the push, DT strategies of wine SMEs.

Advances in geoinformatics	Inf. 23	*"This foreknowledge capability, in which field do I have which oechsle degrees [measuring the sugar content in the grapes] or anthocyanin, that you can get with one hand pass. This is so advanced that there are this Eurorobots who tackle this. The research center X was also a partner on this project. But in Germany they are not allowed to drive through the field- in Spain yes, because they have different legislation. I see this from the perspective that our goal should than be harvester, that could provide different information- most weight,* etc. *This data should be delivered in order to support this smart spinning systems. Harvesters can already do a phenotype reading."*
	Inf. 29	*" . . . can we not attach a kind of scanner* (on the tractor)*? We have so many passes through the vineyard for crop protection, leaf trimming,* etc. *If a simple and affordable system had scanned the leaves to assess if they look dry, are they dark green or yellowish, you could detect the grape color. These would be simple sensory systems that could inform the application if there is a dry or wet zone. This would be helpful things, especially for harvesting later."*
Advances in technology convergence, connectivity, usability	Inf. 28	*"We often have the requirement for the process data to be sent digitally from the press to an external location and thereby do a proactive maintenance, because for example, a valve could break. In addition, to the oenological side, this is very interesting and useful story where digitalization could be applied. This is remote control, so that we as a manufacturer can make remote maintenance and the press is often ready for use much faster than if the serviceman had come."*
Advances in machine learning	Inf. 23	*"there are currently some companies in Germany which deal with precision viticulture. There is the Fraunhofer, there is the Geobox, there are several places that can do this, at least for precision fertilization. Some rely on satellite data, some measure with drones or with NDVI and others with sensors in the vineyard. They all have their algorithms . . . And they then also network the devices for fertilizer application, also zone-dependent fertilizing"*

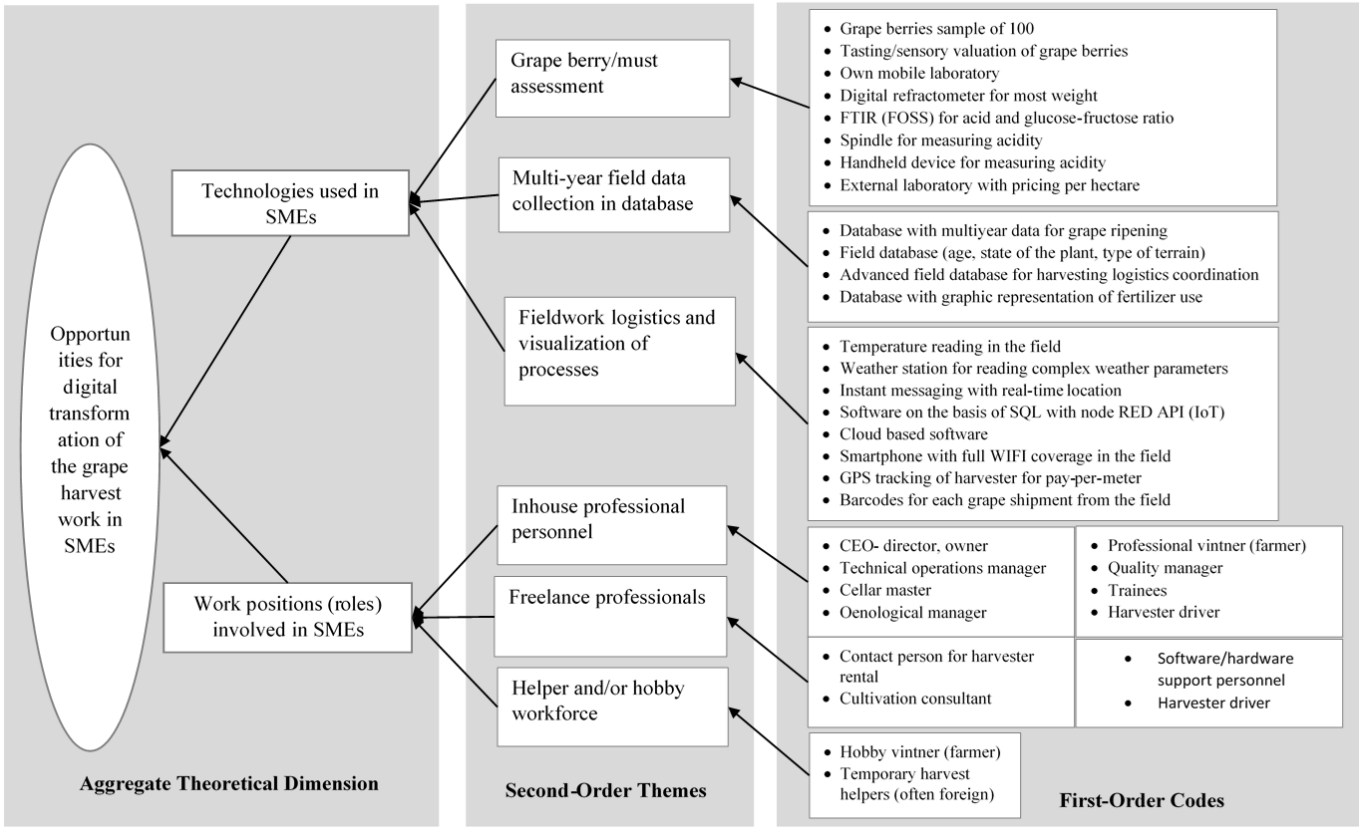

Figure 1. Current state of the grape harvest process regarding technologies used and actors involved.

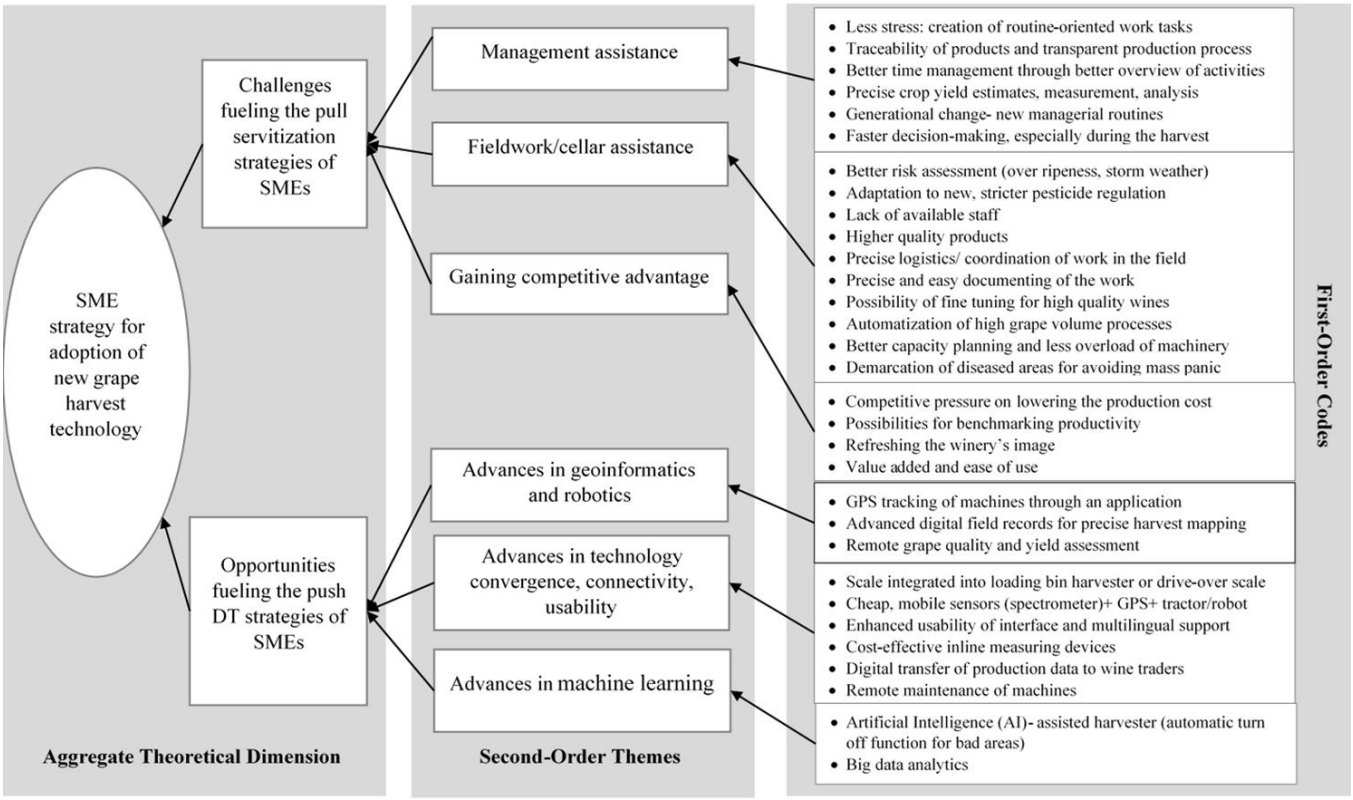

Figure 2. Adoption of grape harvest innovation- challenges acting as pull factors and new technologies acting as push factors.

4. Results

4.1. Technologies Deployed

Different types of technologies are being used in the grape harvest process in the state of Rheinland-Palatinate (RLP). They can all be grouped into three value-creation activities, according to the work task: (1) grape berry/must assessment, (2) multi-year field data collection in a digital database, (3) fieldwork logistics and visualization of processes, as presented in the Table 1 below and Figure 1 later in text.

Grape berry and must assessment take place in the various stages along the wine making process and it is of critical importance for getting accurate data about the state of the grape. This in turn is very important later, for product quality, as it enables conducting crucial activities (plant protection, watering, fertilizer use, harvesting) in the field at the precisely right point and with the right amount. However, acceptance of new routines for grape assessment has traditionally been rather low in Germany.

Multi-year field data collection in a digital database is a collection of data on all field parameters (weather, grape ripening, diseases, treatment, harvest, etc.) as well as later processing in the cellar. This could prove to be a very powerful basis for deploying new technologies like Big Data and Artificial Intelligence to support automated or semi-automated decision-making support systems for grape ripening, harvesting and further processing. Current databases build on SQL or Informix technology, with some new players in the market successfully offering cloud-based databases that facilitate mobile app usage. Some players possess databases that date back forty years, which could be of use for prediction algorithms and big data analytics.

Fieldwork logistics and visualization of processes is one the areas characterized by a big transformation in the recent years with applications across different industries. The advantages of new technologies for logistics are evident to some of the vintners, such as the Informant No. 16. For example, visualization of data serves also to relieve managerial stress, as observed by Informant 12. However, in the RLP wine industry commercial visualization capabilities are still limited as there only few offerings exist, which are predominantly

tailor-made solutions. These companies are still looking for ways to expand in terms of scale and scope. The potential of these technological advances is visible through several successful examples of technology transfer from other agricultural fields to big cooperative wineries. The potential of fieldwork data collection and use is still underutilized because of gaps in data collection and analytics for different purposes. Informant 29 reveals that, in terms of back tracing for new blockchain technologies.

4.2. Roles Involved

Numerous actors with different roles are involved in the grape harvest process, either as individuals or as groups. Three major types of roles are: (1) inhouse professional personnel, (2) freelance professionals, (3) helper and/or hobby workforce. Each group differs in terms of approach, seniority and level of involvement as well as in dedication. For this categories, no verbatim citations have been included, as this aspects have been the object of post-hoc analysis, and no direct referral to this roles have been made during the interviews, but only indirect. The three categories are represented in Figure 1.

The major differences are between entrepreneurial (family) wineries and cooperatives. The family companies' workforce core is made up of family members and salaried professional staff (usually cellar masters), while foreign and domestic helpers are added during the harvest. Cooperatives are marked by the existence of a team of professional staff working on the grape and wine processing and selling, while the grapes are grown by farmers that vary in surface size as well as their professionalism. Some cooperative vintners live off of wine and some are part-time or even hobby vintners. For the sake of the quality, cooperatives possess quality managers who coordinate between management and farmers in order to ensure the matching of the grape quality with the wine production plans for each product category.

4.3. Servitization Needs, Acting as Pull Factors

The market adoption of innovation and the underlying servitization needs of wine SMEs are major themes for technology companies trying to develop and market innovative solutions on the market. Major challenges which pull the new technology adoption in the harvesting process are the key levers that the wineries are trying to take advantage of: (1) management assistance, (2) fieldwork/cellar assistance, and (3) gaining competitive advantage. The most important challenge pushing innovation in both management and fieldwork/cellar assistance is the lack of (qualified) workforce. The three categories and the underlying verbatim citations are presented below in Table 2 as well as categories themselves in Figure 2 later in text.

Wine estate management needs to reduce the stress level through routine-oriented tasks, better traceability and overview of production process for faster decision-making, as Informant No. 16 contends. Furthermore, a new generation of wine estate managers and entrepreneurial vintners is adopting new technology, changing the way things are done, as noticed by Informant No. 30.

Fieldwork and cellar assistance are mostly concerned with possibilities of better assessment of weather and grapes, as well as efficient logistics and coordination of effort between workers. Informant 6 describes how they build their field record database using only Excel sheets. The same informant has also described the process of communication during the harvest, using the same tools as for private communication. In contrast, Informant 21 describes the change when using a specialized software for tracking the work in the field.

Adopting new technology is also connected to the lever of gaining competitive advantage, through lowering production costs but also refreshing winery's image and adding value to the customer offer. As the Informant 7 observes, the new technology is both cheaper and more reliable than the alternative human workforce which would be engaged in processes like grape sorting, therefore having huge impact as a cost-cutting measure. On the other hand, Informant 24 states that regarding field machinery and processing equipment, fine-tuning and quality optimizing options are interesting in the higher-quality segment.

4.4. New Technologies Acting as Push Factors

Technological advances that are perceived as adding the most value and hence motivating for enhancement of capabilities by adopting new technological processes are: (1) advances in geoinformatics and robotics, (2) advances in technology convergence, connectivity, usability, and (3) advances in machine learning. The three categories and the underlying verbatim citations are presented in the Table 3 below, while categories themselves are also presented in Figure 2 later on in text.

Advances in geoinformatics and robotics, the core of precision agriculture, are changing the way things are done in agriculture: from precision harvest mapping to pay-per-meter harvesting services or remote yield assessment. However, Informant 23 notes that although there are many useful technologies, some developments are being slowed down by legal framework in Germany. The informant 29 points to the need for affordable, multi-platform, flexible hardware that can extend functionalities of software in the wine industry.

Advances in technology convergence, connectivity and usability mainly relate to technologies like drive-over scale, cheap mobile sensors, remote machine maintenance. As observed by Informant 28, remote maintenance is one of the major servitization advances, adding considerable value to the users of wine machinery.

Advances in machine learning also seem to be very present and relevant topics in the viticulture, with no mainstream, commercially successful applications of AI or Big Data present, but some important R&D processes are under way, as presented by Inf. 23.

5. Discussion

Regarding the results presented in the Figure 1, previous systematic research of the literature on digital transformation has identified (1) technologies and (2) actors, as two relevant aggregate themes or dimensions. This dichotomy-based approach has previously been deployed by Nadkarni and Prügl [68]. Further relevant literature goes beyond these human and technological aspects, to include also organizational aspects as relevant for redefining the future of work [69,70]. The present research deals with human/work related aspects of DT in Figure 1, while organizational aspects are dealt with in Figure 2, by distinguishing between push and pull factors of SME digital transformation. Previous research has identified a multitude of drivers of digital transformation in SMEs: process engineering, new technologies and digital business development digital leadership and culture, the cloud and data as well as customer centricity and digital marketing [51]. However, present research distinguishes in Figure 2 between pull factors and push factors, as two distinct types of factors influencing the digital transformation strategy of grape harvesting in SMEs. Management assistance, fieldwork/cellar assistance and gaining competitive advantage have been identified as the most relevant pull factors for DT, while advances in geoinformatics, advances in technology convergence, connectivity and usability as well as advances in machine learning have been identified as the most relevant push factors driving the DT of wine SMEs. Previous research on wine industry 4.0 has acknowledged the importance of BMI (Business Model Innovation) [24], while this research contributes to this research stream by exploring technology adoption strategies and DWT, thereby expanding the range of researched phenomena related to a strategic DT.

The findings on the importance of winery business succession adds to the discussions of the impact of family status on the new technology adoption in SMEs, by expanding the understanding on the timing of change in family-owned business. The present study results demonstrate that the generation succession is the time of the greatest change and new technology adoption in a family-owned SME. These findings therefore confirm previous findings that family-influenced SMEs are later at an identification of a discontinuous change, and faster when it comes to implementation ones a discontinuous change has been identified [56]. The findings also contradict the identified a priori reluctance of SME wineries to adopt sustainability innovations if no tangible economic benefits can be identified [57,58], but point to the need to identify the generational cycle stage of family SME wineries. In this sense, future research should take into consideration the generational

cycle stage when considering new technology implementation: discontinuous change appears to be lower-than-average at the end of a generational cycle, and higher-than average at the beginning of a generational cycle, in the years after succession.

The present research explores work and technology as well as the organizational aspects of regional, networked innovation and transformation processes on the example of wine industry in the German state of RLP. Similarly, the regional and networked approach to innovation has previously been conducted on the example of the biotech industry [71,72]. However, the present research does not research network-related phenomena, such are the governance structure, external context or advantages/disadvantages of being part of the network, as there is no formalized network between the researched SMEs. The research deploys a sample of compatible SMEs, who deal with grape harvest innovation to provide insights into important aspects of grape harvest transformation—related to DWT and business transformation. In this sense, future research should carefully consider the possibilities of building wine industry 4.0 networks for digital transformation of work processes as well as whole organizations and industry. The questions of governance structures, external context and the benefits vs. drawbacks for SMEs to be part of the network, should be addressed by future research on wine 4.0 networks.

The results presented are of relevance for managers as they provide empirically based roster of work roles. This roster is suitable for further separate research of each role involved as well as cooperation arrangements inside/outside teams. In addition, a detailed specification of technologies used in the grape harvest process, in relation to the work roles involved has been presented. The results can help managers in identifying training and retraining needs for digital workforce transformation by providing a detailed ontology of roles involved in the grape harvest process. In addition, wine technology companies should be aware of generational successions and create different strategies for transforming family wineries with a stable family ownership and ones in the years after a succession. In this sense, the results provide the basis for digitalization efforts of both workplaces as well as work routines inside a digital workplace transformation in wine industry SMEs. The results can be of relevance for other agricultural SMEs dealing with complex harvest logistics operations. Future research needs to expand this explorative research by conducting quantitative research on work roles, cognitive aptitude and team organization in the wine industry. It also needs to delineate guidelines and major elements for future professionals in the wine industry on how to be successful in the emerging digital wine industry paradigm.

The major limitation of the study is its explorative nature. The models created are for exploratory purposes and therefore lack numeric relationship specification, which are important for theoretical purposes and could be achieved by quantitative studies and structural equation modelling. The creation of the codebook has undergone a rigorous process in an attempt to establish reliability, however biases still might exist regarding both data-driven first-order codes as well as second order themes, and to a lesser extent aggregate theoretical dimension. Further limitation is related to the interviewee selection. Interview partners have been recruited through a winery register, by contacting wineries undergoing or interested in digital transformation, as well as their partner companies in this process. The article does not deal with digital transformation capabilities, but only with its antecedents, namely digital sensing capabilities and digital seizing capabilities, thereby opening possibilities for future research on digital transforming capabilities in wine industry 4.0.

6. Conclusions

The findings of this study enhance the understanding of a still under-researched area of leveraging novel technologies by redesigning jobs and redefining business strategy of SMEs involved in the wine industry 4.0. The research further contributes to the literature on open innovation and redefining professional identity, by defining existing work roles beyond their professional boundaries: skilled permanent workforce, skilled temporary

workforce and amateur temporary workforce. The framework therefore provides ample space for dismantling knowledge boundaries for open innovation, by placing the traditional and future jobs into these three broad categories. Contrary to the findings in the previous literature [48], this research demonstrates the importance of digital tools for advancing managerial and business capabilities in non-IT, traditional SMEs. Managerial assistance tools are found to be important both in wineries dealing with grape harvest for providing grapes for low-cost wines, as well as wineries wanting to get a hold of fine-tuning mechanisms in grape harvest for achieving top quality wines.

The article identifies opportunities and challenges for strategic deployment of new grape harvest technology. It examines both pull-oriented servitization challenges as well as push-oriented, digital transformation opportunities. The results also explore the dynamics of the digital transformation by providing a detailed overview of work roles and technologies used for digital transformation of grape harvest process. Both of these areas contribute to better understanding of the strategic deployment of new technology for the wine industry 4.0. The results also point to the decisive role of work-related (work positions, work processes) and organizational (strategy, business model) aspects in the digital transformation of the wine industry.

The article provides implications on the level of digital sensing capabilities as it presents the multitude of opportunities for DT of grape harvesting process regarding grape berry/must assessment at different stages along the process, multi-year field data collection in a digital database as well as fieldwork logistics and visualization of processes. Contributions toward sensing the opportunities in the field of DWT are provided by defining three types of transdisciplinary work roles in grape harvesting: inhouse professional role, freelance professional role and helper/hobby workforce. These three types of workforce differ in terms of level of involvement in the wine SME as well as professional expertise needed for conducting tasks. The results also provide implications on the level of seizing capabilities. Firstly, two types of forces impacting strategic adoption of grape harvesting technology are presented: pull-oriented servitization strategies and push-oriented digital transformation strategies. Servitization aspects of a technology adoption relate to management assistance, fieldwork and cellar assistance ang gaining a more favorable competitive position or creating competitive advantage. On the other hand, digital transformation aspects involve advances in geoinformatics and robotics, advances in technology convergence, connectivity and usability, as well as advances in machine learning. The role of a technology adoption strategy on an organizational level is to balance between these two important aspects. The interviews have confirmed the critical importance of the grape harvest process for both SME wineries searching for cost-oriented competitive advantages as well as for SME wineries looking for quality-oriented improvements through more precise management of wine taste profiles.

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Appendix A

Table A1. Pull strategies for adoption of new grape harvest technology with detailed descriptions and motivations for overcoming the challenges.

	First-Order Codes	Description of the Challenge	Motivation for Overcoming the Challenge
Management assistance	Less stress: creation of routine-oriented work tasks	The work of a wine manager/entrepreneur is highly stressful and includes often long hours	Any tool promoting work task routinization can help in reducing stress-levels induced by the unstructured nature of the production process.
	Traceability of products and transparent production process	Traceability is being more and more demanded by certification bodies, but also consumers and new digital technologies can help these efforts	Better quality products and more direct risk management, better management options in a crisis situation of having to trace back production steps after a recall
	Better time management through better overview of activities	The work of a wine manager/entrepreneur is highly unpredictable and therefore stressful.	Any tool promoting real-time data tracking can help retain control over production process, while reducing stress-levels induced by a lack of data.
	Precise crop yield estimates, measurement, analysis	Using harvesters often reduces the capability to apply fertilizer and plant protection in the most optimal way, as well as to harvest the best grapes, which can be overcome by precise digital field records.	Better planning capabilities-building for reducing unnecessary work steps, optimize existing ones in scale and scope.
	Generational change- new managerial routines	New generation of vintners is more open to digital technologies and even demands them or even build them themselves. This is especially pronounced after company take-over.	The new generation of vintners and wine entrepreneurs are digital natives and see digital technologies as the only way of doing things, regardless of the previous managerial traditions.
	Faster decision-making, especially during the harvest	Wine entrepreneurs need to coordinate a large number of different stakeholders effectively under tight schedule	Wine entrepreneurs need the capability of being able to make fast decisions in order to keep the high pace of daily duties
Fieldwork/cellar assistance	Better risk assessment (excess ripeness, storm weather)	Wine professionals need reliable and networked tools for assessment of risks.	Making better decisions for reducing crisis situations, reducing unnecessary costs and achieving better quality of a product.
	Adaptation to new, stricter pesticide regulation	Wine professionals are bound by strict and changing regulation which needs to be addressed in a timely manner.	Fulfilling the law requirements with as least effort as possible.
	Lack of available staff	Reliable supply of skilled and unskilled workforce is hard to find.	Reducing the need for large workforce in the production process.
	Higher quality products	Higher quality product means the opportunity for higher prices.	Gaining competitive advantage over competition.
	Precise logistics/coordination of work in the field	Better time-management of the workforce as well as grape processing to in order to lose as least quality due to unforeseen events as possible, for example unwanted fermentation in the sun.	Reducing waste in the production process and thereby making savings.

Table A1. *Cont.*

	First-Order Codes	Description of the Challenge	Motivation for Overcoming the Challenge
	Precise and easy documenting of the work	Fieldwork is very hard to control and document without digital tools.	Better human resource practices in relation to the real work documented- rewards, breaks, productivity
	Possibility of fine tuning for high quality wines	High quality wines need different tuning possibilities along the production process.	Capability-building for answering to every taste profile change in the market and delivering precisely the taste notes needed by the market.
	Automatization of high grape volume processes	High volume grape sorting can be automatized.	No extra workforce needed, thereby reducing many extra work steps in finding, skilling and deploying workforce.
	Better capacity planning and less overload of machinery	Different technological solutions in the field and in the cellar need to be coordinated so that there are no excess capacities as well a no overloads.	Long-term investment planning to avoid incompatible technologies and/or possible losses incurred by misdirected investments
	Demarcation of diseased areas for avoiding mass panic	Having a capability of clearly identifying plants affected by certain disease can avoid treating the whole vineyard and potentially spreading the panic to other vintners in the area.	Clearly delineating risks and addressing them properly.
Gaining competitive advantage	Competitive pressure on lowering the production cost	The wine industry is very competitive and economies of scale are very important.	Providing the lowest price possible in certain price ranges.
	Possibilities for benchmarking productivity	Digital tracking of activities and productivity can enhance industry benchmarking,	Identifying the possibilities for further optimization of processes.
	Refreshing the winery's image	Deploying the newest or the most exotic technology can enhance the company image inside the industry itself.	Presenting the winery as future-oriented and innovative.
	Value added and ease of use	The new technology introduced needs to be highly practical and usable as vintners are no hackers or digital natives.	The vintner needs to see clear value added from new processes and he has to clearly understand the way it can be deployed.

Appendix B

Table A2. Push strategies for adoption of new grape harvest technology with detailed descriptions and motivations for seizing the opportunities.

	First-Order Codes	Description of the Opportunity	Motivation for Seizing the Opportunity
Advances in geoinformatics and robotics	GPS tracking of machines through an application	All the vehicles in the field can be controlled via one interface.	Increasing the coordination and planning capability, as well the quality of short-term decision-making.
	Advanced digital field records for precise harvest mapping	Digital records are the basis for connecting all other devices through an interface.	Reducing excess costs and new possibilities through different digital devices, many still in experimental use.

Table A2. *Cont.*

	First-Order Codes	Description of the Opportunity	Motivation for Seizing the Opportunity
	Remote grape quality and yield assessment	Getting the data from the field with no need to be present all the time.	Reducing field visits during ripening period and better resource planning.
Advances in technology convergence, connectivity, usability	Scale integrated into loading bin harvester or drive-over scale	Integrated scales can help with getting the data on the quantity of grapes for processing.	Better planning of the grape processing for lower costs and higher quality.
	Cheap, mobile sensors (spectrometer)+ GPS+ tractor/robot	New affordable sensors are being developed for different kinds of devices and for different uses.	Enhancing capabilities of existing hardware with low additional investments needed.
	Enhanced usability of interface and multilingual support	Interfaces between different hardware and software components need to be optimized as well as usability for a diverse workforce.	New devices need to be compatible with old ones and design for use by an international workforce.
	Cost-effective inline measuring devices	Affordable solutions need to be developed in order to enhance grape and wine processing even further.	Higher quality wine on a relatively tight budget.
	Digital transfer of production data to wine traders	The digitalization of production data enables automatic transfer of data to wine traders, enabling the customers to profit from better and more reliable data in an otherwise complex industry.	Providing production data in a modern and accessible way with no extra cost of additional certification.
	Remote maintenance of machines	There is a possibility to conduct remote maintenance for some high-end grape processing facilities.	Time and effort saving, better coordination with technical support.
Advances in machine learning	Artificial Intelligence (AI)-assisted harvester (automatic turn off function for bad areas)	New harvesters are being launched on the market, which can automatically recognize bad grapes and not harvest them.	Considerable quality improvement closer to hand harvest, with no extra effort needed by the harvester driver.
	Big data analytics	Putting to use an abundance of historical digital data in some historic companies in order to make better decision in relation to weather, ripening and harvest timing.	Harness the power of experience currently buried in decades of unused historical data, to enhance the vintner decision-making as well as capabilities of machinery.

Appendix C

Table A3. Questionnaire with open-ended questions used to conduct semi-structured interviews with SMEs on the left and software and hardware producers on the right.

Questions for Wineries	Questions for Wine Software and Hardware Producers
1. Please describe the harvest planning process in your company in detail (which actors are involved, which routines have been developed, which technologies are being used, how long does the whole process lst, which key competences and capabilities are needed?).	1. What are the latest Industry 4.0 technologies that could be used for grape ripeness measurement, harvest planning and harvesting itself? Which technologies have already been implemented, which are coming soon and which have already been used in other areas of agriculture?
2. How does the digitalization of data transfer between grape growing grape and grape must processing look like in your company?	2. Which key competencies and skills are required or will be required in the future? How well is the (university) education adapted to these changes? To what extent is (university) education pursuing or promoting these changes?

Table A3. *Cont.*

Questions for Wineries	Questions for Wine Software and Hardware Producers
3. Which data are available in digitalized form, at which pace, and what are the expectations/needs from the company in this sense? (Geolocated information, Vineyard types, GPS technology or other, planned vs. Actual harvest, grape variety, quality parameters, must weight, acidity, extent of decay, type of decay, etc.- which optimizations in this sense would benefit the most the production process?)	3. To what extent is the data transfer between grape production and grape processing already digitalized?
4. What motivates the optimization of interfaces between different IT systems in your company?	4. Which data is already digitalized (from a technical point of view), at what speed can they be delivered? (e.g., geo-positioning—via GPS or otherwise, harvest volume: estimated and actual, grape variety, quality parameters such as must weight/acidity, botrytis content, type of decay, etc.)
5. What is the structure of your employees when it comes to the digitization perspective or motivation for digitization? (Are there differences in the acceptance of digitalization? If so, which ones and why?)	5. Which data could be digitized (from a technical point of view) and at what speed could it be delivered? (e.g., geo-positioning-via GPS or otherwise, harvest volume: estimated and actual, grape variety, quality parameters such as must weight/acidity, botrytis content, type of decay, etc.)
6. If you use harvesters: how does the planning and consultation work with regard to harvester take place? (Do you harvest according to local availability or are quality aspects in the foreground?)	6. Which Industry 4.0 technologies could be used in terms of planning and consultation with the harvester?
7. How do you deal with purchased goods (grapes, must or wine)?	7. What could the latest technologies do when it comes to product traceability systems? (e.g., because of product safety and faster collection of defective series, traceability of sales of products back to raw material receipt)
8. What are the needs regarding tools/systems for product traceability? (e.g., because of security and quick collection of faulty series—from sales of the products back to raw material receipt)	8. How dynamic have changes and innovations in harvest planning been over the past 10 years? (What has changed? To what extent?)
9. How dynamic have the changes and innovations of harvest planning been over the past 10 years? (What has changed? To what extent?)	9. What is the outlook for the changes and innovations in the area of harvest planning in the next 10 years? (What will change? To what extent?)
10. Have measures to improve the harvest planning process and/or grape logistics already been planned? (If yes, which?)	
11. What are the priorities for innovation in your company? (Please give examples for each applicable category: increase in efficiency—less waste of resources, increase in effectiveness—achieve goals with greater success, increase quality—produce products with higher/more stable quality)	
12. How do you deal with innovations? (More carefully, step by step, or rather as a paradigm shift and one-off, radical change)	

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Organizational and Environmental Factors with the Mediating Role of E-Commerce and SME Performance

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Abstract: The study investigates the mediating role of e-commerce through organizational and environmental factors with small and medium enterprises (SMEs) performance. The study follows a cross-sectional survey method approach. The study's theoretical foundation is based on the resource-based view (RBV) and diffusion of innovation (DOI) theory. The current research identifies four manufacturing SMEs' strata based on participation in the country's exports using a stratified proportional random sampling technique. The research questionnaires were distributed among 700 top and middle-level managers of manufacturing SMEs. The data were analyzed by applying partial least square structural equational modeling (PLS-SEM) to examine the relationship between the exogenous, mediator, and endogenous variables. The finding reveals that top management support and competitive pressure have a significant positive impact on the use of e-commerce direct and mediation. At the same time, the adoption cost and government support have an insignificant impact on e-commerce usage. This study results can be used to enhance the use of e-commerce in Pakistan's manufacturing SMEs to improve the country's overall exports.

Keywords: use of e-commerce; manufacturing SMEs; organizational; environmental; firm performance

1. Introduction

Before starting on firm performance, it is vital to highlight that since the 1930s, researchers and practitioners together have pursued to understand underlying drivers of innovation and its effect on firm performance. However, the quest to link innovation with firm performance is somewhat obtained by interpreting innovation as culture [1] and innovation as a technology adoption [2]. Although several scholars have focused on the current decade, there are plenty of gaps in our understanding of the link between technology innovation and firm performance [3]. Likewise, open innovation subsequently increases SMEs' performance; for instance, Alibaba.com has become the world's largest e-commerce global platform for SMEs [4]. The dynamic, open innovation has mainly three processes: the inside-out process, the outside-in process, and the coupled process. All three processes must cross the regional boundaries by focusing on environmental factors and internal and external characteristics to implement open innovation [4,5] successfully. Thus, the study argues that the use and effective implementation of open innovation technology requires both the organizational and external environmental factors to implement digital technologies in the firm's innovation process.

In the modern era of digitalization, the evolved phenomenon of e-commerce, particularly in emerging markets, is growing rapidly, and enterprises are starting to prefer to buy and sell online. The more significant economies of developing countries, India and China, are shifting their operations day by the day from conventional businesses to click-and-mortar. The Indian e-commerce market growth is anticipated to reach 64 billion US dollars by the end of 2020 [5]. Likewise, according to China's online trade market data, China has already reached a 574 billion US dollars market in 2018 [6].

Likewise, the fast-growing development in the e-commerce market alters the ways to operate a business in large as well as small industries [7]. However, e-commerce usage in small and medium enterprises (SMEs) has significantly increased and is continuously making progress.

In the 21st century, SMEs are enhancing the sustenance and growth of numerous economies of the globe. For instance, according to the Asia pacific economic report, SMEs contribute over half of the employment and over 97% of all businesses across Asia-Pacific Economic Cooperation (APEC) economies [8]. Additionally, SME's share in the GDP of APEC countries is ranging from 20 percent to 50 percent. Similarly, In Association of Southeast Asian Nations (ASEAN) countries, SMEs account for 63.3 percent of employment, and their share in total gross value is around 42.2 percent [9]. In the same way, Zafar and Mustafa [10] said, on average, in low-income countries, SMEs contribute approximately 70% in employment and 60% in the country's GDP. Moreover, in middle-income countries, SMEs are contributing 95% to employment and 70% to GDP. Hence, it is depicted that SMEs are equally important for every economy of the world.

In addition to GDP, exports are considered another critical factor analyzing the economic growth of any country. SMEs' participation can also escalate the country's exports [11]. Though in regional countries like China, India, and Japan, SMEs contribute 60%, 37.5%, and 55%, respectively, of their exports. According to the World Trade Report (2016), SMEs' participation in exports of Pakistan was estimated at 24.8%, which is very low compared to the regional competitors. Hence, Pakistani SMEs are going through many challenges restricting their development in the long term [12]. Likewise, the adoption of new technology is an essential challenge faced by Pakistani SMEs.

Theoretically, the study deals with combining the disintegrated scholarly work about the TOE model on e-commerce usage. Previous scholars also elucidate the importance of technology innovation change with the significance of the factors, i.e., organizational and environmental [13]. Concerning the theoretical contribution of e-commerce usage, its integration as a mediator adds to a vital inclusion. In addition to that, drawing from the RBV perspective, the present study contributes by providing several theoretical relationships between TOE model resources and e-commerce usage as capability.

Practically, SMEs are embracing innovation activities to improve production processes [14]. There have been numerous studies on the adoption of e-commerce in the developed countries, but it is still at the earlier stage in developing countries [15]. In addition, many developing countries are still far behind in the adoption of e-commerce [16]. Similarly, Pakistan is also at the initial stage in the use of e-commerce [17].

According to the Global Competitiveness Report (2018), Pakistan is placed at 127 out of 140 states in terms of information communication technology (ICT) adoption. According to State Bank of Pakistan (SBP) (2019), economic experts forecasted that e-commerce sales would reach 1 billion US$ by the end of the fiscal year 2020 [18]. Likewise, Table 1 shows the negative growth rate change in exports of manufacturing industries of Pakistan. Therefore, e-commerce usage in Pakistani SMEs needed further investigation, and it is vital to consider organizational and environmental factors for successful usage of technology like e-commerce in SMEs [19]. Thus, the current study aims to contribute to the existing knowledge by using e-commerce as a mediating variable between organizational and environmental factors and SMEs' performance.

Table 1. Manufacturing industries' growth in exports of Pakistan.

Percentage Growth Change in Exports of Manufacturing Industries of Pakistan	2018–2019 (Percentage Change)
Textile industry	0.08
Sports goods industry	−9.04
Surgical industry	−1.46
Leather industry	−8.41
Chemical and pharma	5.68
Engineering goods	−10.81
Cement	32.81
Carpet rugs and metals	−12.5

Source: [20].

In Pakistan's manufacturing SMEs, it is needed to study the surgical industry in terms of technology usage like e-commerce. The surgical industry's contribution to total exports of the country is decreasing compared to the previous years. Pakistan's surgical instrument industry contributes 284.9, 254.4, 262.7, and 221.7 million US dollars in total exports of 2014, 2015, 2016, and 2017, respectively. In a similar vein, in the year 2018–2019, it is evident that there is a negative change of 1.46 percent in terms of exports' growth (Pakistan Bureau of Statistics, 2019). Likewise, there was a slight increase of 0.5 percent in sports goods SMEs in 2017–2018. The reason was the use of Pakistani football in Fédération Internationale de Football Association (FIFA) World Cup 2018. Unfortunately, again in the fiscal year 2018–2019, sports goods growth declined by 9 percent and 7.35 percent in terms of exports. In addition to sports goods, the leather industry's export growth also had a negative change of 8.41 percent in the fiscal year 2019. Similarly, the exports of textile manufacturers witnessed a slight growth of 0.1 percent and still stood at US$ 9.99 billion in the fiscal year 2019 as compared to the US$ 9.98 in the fiscal year 2018 [20].

The research findings insights about organizational and environmental factors through the indirect relation of e-commerce usage to SMEs' performance. The empirical investigation reveals that top management support and competitive pressure have a significant relationship direct as well as an indirect effect of the use of e-commerce as a mediation on firm performance [21,22]. However, adoption cost and government support do not appear statistically significant with e-commerce usage.

The remainder of this research consists of four sections. In the second section, the study highlights the detailed literature review and TOE model factors with the use of e-commerce and SMEs' performance. Section 3 focuses on the research methodology, which comprises sample size, data collection tools, and analysis. In the next Section 4, it will be interesting to read about the research's analysis and key findings. Section 5 ends up with the remarkable conclusion and limitations of the study.

2. Literature Review

2.1. SMEs Performance

SMEs' performance is considered a significant indicator of the effectiveness of organizations. SME's performance refers to an indicator consists of market share, firm profitability, and growth of the firm in which profitability and firm growth are necessary elements of SMEs' performance, and these elements are used to measure the effectiveness [23]. SMEs' performance was used as an indicator to assess the businesses' growth in an economy. SMEs' performance is one of the major concerns in today's businesses [24]. Moreover, the performance of SMEs is essential for for-profit organizations [25]. SMEs' performance is an essential indicator of attaining the firm [26]. Most of the prior researchers paid less attention to which indicators should be included in SMEs' performance and how SMEs' performance should be measured [26]. Mainly scholars have measured the SME's performance with profit, survival, value, growth, and public image [27].

2.2. B2B E-Commerce

In a broader sense, previous business to business (B2B) electronic commerce adoption research has investigated the issues from a range of theoretical foundations. For instance, researchers have explored how technology, organization, and environmental (TOE) context factors examined the adoption/usage of B2B electronic commerce [28]. The main advantages of using B2B e-commerce include acquiring substantial returns by increasing performance, revenue, new business opportunities, reducing inventory, and improving customer relations [29]. Currently, Pakistan is far behind in electronic commerce usage from regional countries like Turkey, China, and India [30]. In 2019, Pakistan's Internet users' number was estimated to increase to 56 Million. Therefore, the present study addresses this problem by proposing the mediating role of the use of e-commerce with TOE model factors.

2.3. Adoption Cost

Previous literature recognized that adoption cost has two streams related to technology innovation that are positive and negative [31]. In addition, the innovation's relative cost is more critical for small firms as compared to the large firm due to the less availability of the resources, such as finance, labor, and material [32]. Opposing this, the relationship between transaction costs and firm performance is negatively associated [33]. However, the direct influence of adoption cost on firm performance is a missing link. Therefore, more insights require at the firm level to identify the relationship between productivity, innovation, and operational efficiency. Different types of innovation costs have a different significant impact on business performance [34]. Hence, the direct relationship between adoption cost and firm performance is still in the infancy stage in the literature.

2.4. Top Management Support

Top management usually makes timely decisions to achieve the firm's ultimate goals; thus, the possible benefits and hurdles in taking the tough decision of adopting new technology like e-commerce. As defined in previous literature, TMS and encouragement are vital criteria for the adoption of IS technology, including e-commerce [35]. Similarly, top management knowledge related to the benefits of the adoption also creates substantial value. At the same time, it is crucial in the planning and defining role of information technology (IT) in the firm [36]. Moreover, the organization's new technology will be more successfully implemented if its employees recognize its adoption returns and support the managers [37]. Additionally, top management support is also helpful in reducing the employees' resistance to change. Several other factors like manager's attitudes towards IT, innovativeness, experiences, and IT knowledge directly affect SMEs' adoption process. Therefore, TMS is a crucial factor in e-commerce, and untimely, it may increase SMEs' performance in Pakistan.

2.5. Government Support

It is indisputable that government agencies are a well-established factor for organizational innovativeness [38]. In literature, government support has been measured in terms of two indicators. The first indicator is related to government availability to technology usage like the Internet. The second indicator is associated with government encouragement and assistance to encourage SMEs for e-commerce adoption. Notably, ref. [39] have investigated that businesses operated under restrictive government policies are less likely to adopt IT adoption. In addition, ref. [40] has submitted in their findings that government, through the influence of regulation, can positively as well as negatively impact the adoption of information technology innovation. Similarly, ref. [41] argues that one of the critical and influencing drivers of Internet commerce adoption is government support while investigating the TOE drivers of e-commerce adoption. Therefore, in the current study, government support is expected as an influencing factor for Pakistani SMEs.

2.6. Competitive Pressure

Competitive pressure refers to the "pressure felt by the competitors within the same industry" [39]. In previous literature, it is argued that competitive pressure affects technology adoption when a firm identifies that this adoption of technology leads towards competitive advantage and, ultimately, firm performance [42]. The general view held by all economists is that competition increases the chances of adoption of an innovation. It was argued in the literature that IT adoption had affected the competition in three ways; by changing the rule of competition, industry structure, and by providing new business methods in the industry. Previous studies have shown that competition intensity is positively influenced by the degree of e-commerce adoption [43]. Therefore, the present study has created a missing link between competitive pressure and firm performance through the use of e-commerce.

2.7. Theoretical Foundation and Framework

According to the diffusion of innovation (DOI) theory, innovation is defined as "an idea, practices, or object that is perceived to be new by an individual or another unit of adoption" [44]. While diffusion refers to "the process by which an innovation is communicated through certain channels over time among the member of a social system" [44]. Similarly, Roger explains that diffusion is often related to the efforts to extend the innovation by good listeners by using the communication channels. However, adoption is more associated with the decision to agree and use innovation; for instance, e-commerce usage [45].

The TOE framework is also applied in numerous studies related to technology innovation and technology adoption/usage studies. For instance, electronic data interchange (EDI) adoption, e-market adoption, web 2.0, and enterprise resource planning (ERP) adoption [46–49]. However, the present study focuses on top management support (TMS) and adoption cost (AC) as an organizational context. Likewise, government support (GS) and competitive pressure (CP) as environmental factors.

In addition to TOE and DOI theories, a resource-based view (RBV) is also applied in numerous technology usage/adoption studies. In this study, RBV is employed as the underpinning theory. The primary contention of the RBV theory is resource heterogeneity, that is, capabilities, different resources, and immobility of the firm [50]. These unique resources consist of specific characteristics like economically valuable, relatively scarce, difficult to imitate by competitors, and non-substitutable by other market players. Firms have different resources and efficiently and effectively utilize their resources to gain a competitive advantage [51]. The present study has contributed to the RBV theory by considering the use of e-commerce as a capability to get a competitive advantage over rivals.

Theoretically, previous scholars have discussed blockchain adoption [52], cloud ERP adoption [53], e-government usage [54]. Moreover, it is suggested that e-commerce usage/adoption as a mediator needed further research, particularly for developing countries [16]. Moreover, very few studies have looked into the TOE model's organizational and environmental dimensions [55] combined with DOI and RBV theories. Hence, the highlighted practical and theoretical issues merit further study, and this study extends the existing knowledge by answering research questions in developing countries, particularly in manufacturing SMEs of Pakistan. The theoretical framework of the study is consisting of four independent variables, one mediating variable, and one dependent variable, as shown in Figure 1.

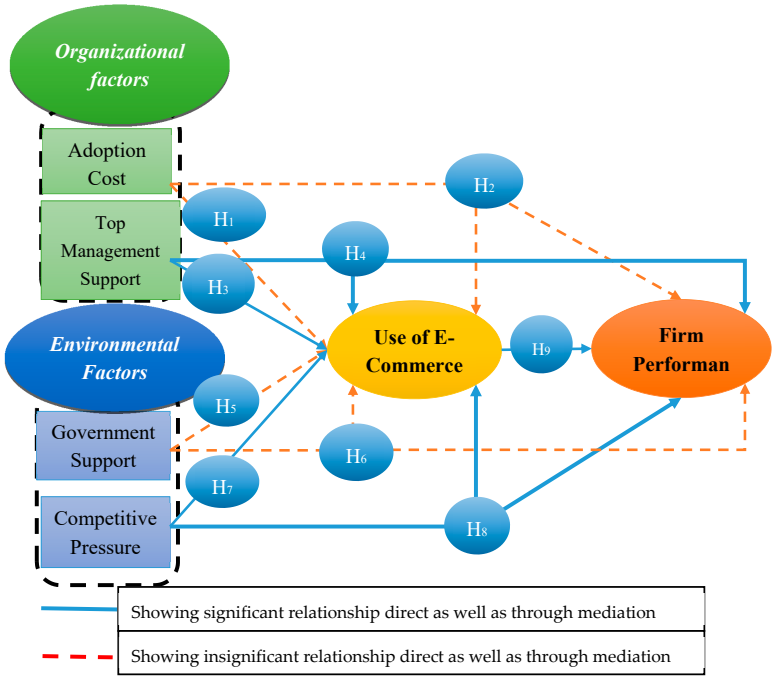

Figure 1. Theoretical framework. Source: authors.

2.8. Hypotheses Development

2.8.1. Adoption Cost, Use of E-Commerce, and Firm Performance

The cost associated with the usage of e-commerce is measured as an influencing factor in SMEs and is known as adoption cost [56,57]. At the same time, in the literature, it is argued that the less cost of adopting technology, the more frequently it will be implemented in the organization [58,59]. Previous literature recognized that adoption cost has two streams related to technology innovation that are positive and negative [31]. The innovation's relative cost is more critical for small firms than large firms [60]. This is because of less resource availability in small and medium firms, such as finance, labor, and material [32]. In addition, there is a significant association between IT investment and firm performance [61].

Moreover, the literature suggested that several factors affect open innovation and SMEs performance, such as external networking, which is necessary to market B2B global market, and available resources like the cost of adopting a particular technology innovation [62]. On the other hand, there is a negative relationship between transaction costs and firm performance [33]. However, the direct influence of adoption cost on firm performance is a missing link. Therefore, more insights require at the firm level to identify the relationship between productivity, innovation, and operational efficiency. Different types of innovation costs have a different significant impact on business performance [34]. Hence, the indirect relationship between adoption cost and firm performance through e-commerce is still in the literature's infancy stage. The discussion formulates the below hypotheses:

Hypothesis 1. *Adoption cost has a negative influence on the use of e-commerce.*

Hypothesis 2. *Use of e-commerce mediates the relationship between adoption cost and firm performance.*

2.8.2. Top Management Support, Use of E-Commerce, and Firm Performance

Top Management Support refers to the firm's leadership that escalates the significance of e-commerce adoption and their commitment to it [63]. Previous empirical studies observed the positive relationship between top management support and firm performance [64,65]. Likewise, technological innovation (e-commerce) has been systematically influenced by top managers' support in the SME [66].

Top Management support to open innovation can be imitated for taking strategic and operational decisions. Further, management support can be reflected to provide awareness of how open innovation can further enhance the organization's innovativeness [67]. Thus, top management is an essential element that can force with or against the adoption process. If top management works positively to adopt new technology only, it may reduce organizational resistance for change like e-commerce [68–70]. The former scholars are more towards the subjective psychological state regarding the potentials of e-commerce. While the latter refers to the steps taken to enable e-commerce in their firms [71]. Hence, top management support is an indispensable factor and served as a strategic resource to increase firm performance [72]. Therefore, based on the stated arguments, the following hypotheses were established:

Hypothesis 3. *Top management support has a positive influence on the use of e-commerce.*

Hypothesis 4. *Use of e-commerce mediates the relationship between top management support and firm performance.*

2.8.3. Government Support, Use of E-Commerce, and Firm Performance

Literature reveals that SMEs' sectors are primarily influenced by governmental policies and lack of innovation implementation [73,74]. This implies that the government should take several corrective and preventive measures to solve numerous problems, such as establishing an R&D department to compete in the international market and making technological advancements to improve products and services.

In the 21st century, open innovation is the primary concern of industries. However, Australian and Singapore governments have facilitated the promotion of online open innovation platforms [75].

However, there is very rare research available that identified the firm's performance with government support and innovation, particularly in developing countries [76]. However, previous studies have also used government support in innovation usage like e-marketing, e-government, e-banking, and e-learning [60,77–79]. Thus, all the above-discussed issues are causing a direct or indirect effect on SMEs' performance, which needs to be tested with the RBV theory. At what level government support impact the firm performance? Moreover, this literature is filled with the help of the current study. The discussion leads to the following hypotheses:

Hypothesis 5. *Government support has a significant positive influence on the use of e-commerce.*

Hypothesis 6. *Use of e-commerce mediates the relationship between government support and firm performance.*

2.8.4. Competitive Pressure, Use of E-Commerce, and Firm Performance

Competitive pressure refers to the "pressure felt by the competitors within the same industry" [39]. In previous literature, it is argued that competitive pressure affects technology adoption when a firm identifies that this adoption of technology leads towards competitive advantage and, ultimately, firm performance [42,80]. Similarly, the study shows that firms are moving towards innovation adoption as competitive pressure increases. However, the literature suggests that the pressure on SMEs has increased unprecedented challenges [81].

Moreover, open innovation is an approach that focuses on new ideas and knowledge generated from the outside environment of the firm, such as competitive pressure [82]. Likewise, a study by [83] indicated that the top market players could make industry standards, and these standers force other firms of the market to follow them. Therefore, it implies that to maintain the position of competitiveness, SMEs must adopt the technology to grab maximum market share both at local and international level and such activity upsurge the confidence level of the customers and help the company to increase their sales to pay back the investment in a short period [47,84] which eventually increases firm performance [85–87]. The above discussion proposed the following hypotheses:

Hypothesis 7. *Competitive pressure has a significant positive influence on the use of e-commerce.*

Hypothesis 8. *Use of e-commerce mediates the relationship between competitive pressure and firm performance.*

2.8.5. Use of E-Commerce has a Significant Positive Influence on Firm Performance

The term open innovation has created a new value for a firm by combining technologies and markets such as inter-organizational networks and national innovation systems beyond the boundaries of the firm [4]. Consequently, open innovation dynamic capabilities allow firms to crab outbound opportunities by using information technology. Thus, the use of e-commerce as innovation openness can fascinate customer interaction with the seller globally, which eventually enhances the SMEs' performance.

In the past literature, e-commerce usage is considered a platform to interact with other business partners, which leads to firm performance [88]. Likewise, this usage is fascinating customer interaction with the seller locally and globally as well. Furthermore, [89] confirmed that the use of e-commerce had changed many operations in the business; it is not only changed the ways of selling, buying, and overall communication of business partners to change the business perspective from "production excellence" to "customer intimacy". Despite great attention by the government, the adoption of electronic commerce is still behind in developing countries. Moreover, [90] reported that e-commerce has a positive impact on operational performance.

On the contrary, Sila [91] studied the consequences of e-commerce usage and confirmed that e-commerce uses do not directly impact operational performance. Instead, it improves the performance of business operations first and later enhances operational performance. Therefore, the current study

includes e-commerce usage as a mediator in the framework to help Pakistan's SME sector. In addition, to enhance the performance of SME's, all the factors were studied thoroughly with the help of previous literature to motivate the SME's to analyze the lacking in their firms and to adopt different ways and methods to resolve their current issues and maximize their profits, market share, financial position, and survival for the more extended period. The above discussion formulates the following hypothesis:

Hypothesis 9. *Use of e-commerce has a significant positive influence on firm performance.*

3. Methodology

3.1. Research Design, Measures and Sampling Technique

Research design can be referred to as a plan or procedure used to conduct the study, collect data, and analyses variables stated in the research problem. It is essentially an outline and plans to explore the research to answer the research questions. In this research, a cross-sectional survey method was used. Survey research analyses the association for different variables in the social system such as institutions, organizations, and communities. Moreover, the unit of analysis means the object that is studied in research [92]. The subject can be an individual, an organization, or a household relevant to the researcher's studies [93]. The study has used the organization as a unit of analysis, and SME managers working at the top and middle-level positions are considered respondents.

The present study has followed a closed-ended questionnaire composed of two sections: section one covers demographic information concerning respondents and their firms, while section two covers questions pertaining to constructs used in the research frameworks of the present study. In addition, a concise overview of both subsections is given as follows: Section A consists of six questions; four questions relate to the respondent's profile, including gender, age, education, and position in the organization's hierarchy; while the remaining two questions were related to the firm, i.e., industry type and experience of using e-commerce. Section B includes six adapted questionnaires from previously published studies; the scale of firm performance was modified in line with [94] and [95]; to measure adoption cost, three (03) items scale was taken from [96]; Likewise, four (04) element questionnaire to measure top management support was adapted from [97]; government support scale was adapted from [98] with four (04) items; competitive pressure is measured with the [95] scale of six (06) items; Use of e-commerce was assessed by adapting seven (07) items scale from [99].

There are about 3.8 million registered companies in Pakistan, including 90 percent of small and medium-sized companies across the country approximately [100]. The present study identifies four manufacturing SMEs' strata based on participation in the country's exports by using a stratified proportional random sampling. The total population of manufacturing SMEs that participated in exports of Pakistan is 6561, as shown in Table 2. However, 364 manufacturing SMEs were chosen according to the sample size table provided by [101]. To collect the research data, a total of 700 questionnaires were sent to the top and middle-level managers of selected manufacturing SMEs as shown in Table 3.

3.2. Data Collection Procedure

The researcher has collected the data with adapted questionnaires from the top and middle-level managers of Pakistan's targeted manufacturing SMEs. The questionnaire is constructed with a Likert scale of seven scales, anchored to "strongly disagree" (1) and "strongly agree" (7). The questions were structured to explore the mechanisms which will affect Pakistan's SMEs' performance and use of e-commerce. Precisely, the data for this study is collected for three and a half months, starting from April 2020. By keeping in view, the nature of the manufacturing firms' managers, the survey was conducted via the Google form; the questionnaire was shared by email (addresses taken from the Sialkot chamber of commerce) and WhatsApp community groups SMEs managers as presented in Table 4.

Table 2. The population of the current study.

Manufacturing SMEs	Number of SMEs Participated in Exports
Textile	1304
Leather goods	1540
Sports goods	2071
Surgical instruments	1646
Total	6561

Source: [102].

Table 3. The sample size calculation is based on the sampling technique.

Strata	Proportionate	Sample Size (S)
Textile	1304/6561 = 0.198	700 × 0.198 = 139
Leather	1540/6561 = 0.234	700 × 0.234 = 165
Sports	2071/6561 = 0.315	700 × 0.315 = 221
Surgical	1646/6561 = 0.250	700 × 0.250 = 175
Total		700

Table 4. Response rate of questionnaires.

No of Questionnaire	Response Rate %
Distributed	700
Returned	383
Incomplete	15
Returned and usable	364
Response rate percentage	54.6%
Usable response rate	52.5%

4. Data Analysis and Findings

4.1. Multivariate Skewness and Kurtosis

The present study assessed the multivariate skewness as well as kurtosis by using web power software available at https://webpower.psychstat.org/models/kurtosis, as suggested by Sarstedt, Ringle [103] and Cain, Zhang [104] before further analysis. After analysis, the result revealed that the collected survey data were not multivariate normal; Mardia's multivariate skewness and kurtosis were ($\beta = 2.80$, $p < 0.01$) and ($\beta = 48.98$, $p < 0.01$) respectively, as shown in Figure 2. Therefore, in the present study, the researcher has used PLS-SEM by SmartPLS software due to the multivariate normality issue.

```
Sample size:  364
Number of variables:  6

Univariate skewness and kurtosis
                          Skewness   SE_skew   Kurtosis   SE_kurt
Adoption.Cost          -0.15471913 0.1278633 -0.8541290 0.2550403
Competitive.Pressure   -0.05483252 0.1278633 -0.4245693 0.2550403
Firm.Performance        0.09132886 0.1278633  0.3778676 0.2550403
Government.Support     -1.08254441 0.1278633  1.1419175 0.2550403
Top.Management.Support -0.10921719 0.1278633 -0.2235066 0.2550403
Use.of.E.commerce      -0.18948597 0.1278633  0.2902834 0.2550403

Mardia's multivariate skewness and kurtosis
                b           z      p-value
Skewness  2.807079 170.2960976 1.822986e-13
Kurtosis 48.980827   0.9549428 3.396066e-01
```

Figure 2. Mardia's multivariate skewness and kurtosis.

4.2. Respondents Profile

This section explains the profile of the respondents of the current study as shown in Table 5. The demographic information covers information related to respondents and their firm.

Table 5. Demographic data and respective percentages.

Demographics	Frequency	Percentage (%)
Gender		
Male	198	54.39
Female	166	45.60
Age group		
21 to 30 years	124	34.0
31 to 40 years	152	41.7
40 years and above	88	24.17
Experience in using e-commerce		
Less than 1 year	164	45.05
More than 1 to 2 years	112	30.7
More the 3	88	24.1

4.3. Descriptive Analysis of Latent Construct

The descriptive statistic in Table 6 exhibited that scores related to mean, minimum, maximum, and standard deviation values were calculated on a Likert scale ranging from 1 (Strongly disagree) to 7 (Strongly agree). Hence, descriptive statistics show that mean values ranging from 4.36 to 5.44, and standard deviation values range from 0.91 to 1.43. Moreover, Cronbach's alpha results are in line with the standard values, i.e., at least 0.65 is considered average reliability, and 0.70 or higher indicates that the instrument has a better reliability standard [105,106].

Table 6. Descriptive statistics and Cronbach's alpha.

	Min	Max	Mean	SD	Cronbach's Alpha
Adoption cost	1	7	4.466	1.432	0.773
Firm performance	1	7	4.638	0.965	0.863
Top management support	1	7	4.365	1.139	0.967
Government support	1	7	5.441	0.916	0.841
Competitive pressure	1	7	4.783	0.965	0.809
Use of e-commerce	1	7	4.809	0.96	0.856

4.4. Assessment of Measurement Model

The present research examined the validity and internal consistency reliability of the model to evaluate the outer model, also known as the measurement model [107] and it is shown in Figure 3.

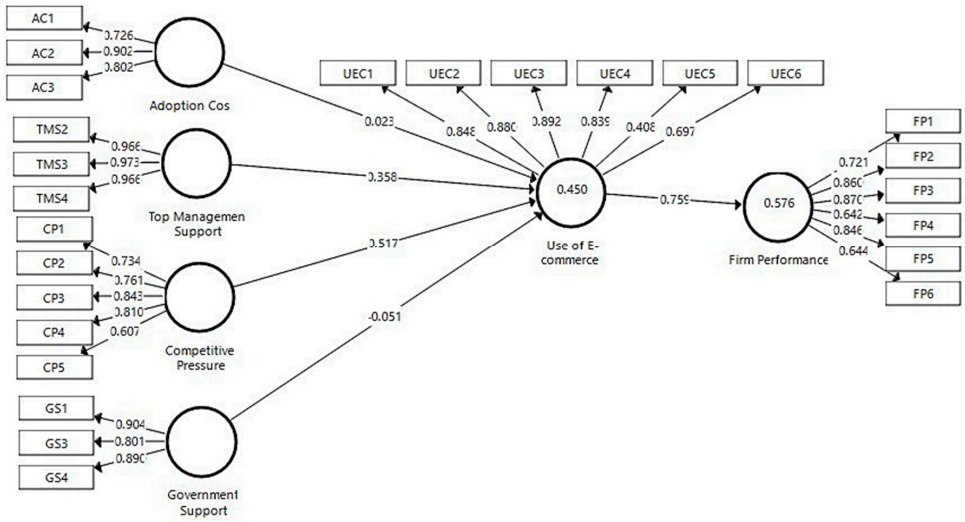

Figure 3. The PLS algorithm of the measurement model.

4.4.1. Internal Consistency Reliability and Convergent Validity

The composite reliability (CR) of the model was tested to measure the internal consistency reliability. Table 7 showed that all values are above 0.60, which fulfilled the criteria [108]. Likewise, convergent validity is elucidated by [109] as "the degree to which a latent construct explains the

variance of its indicators." Moreover, Table 7 shown that 50% of each variance is attained by each construct (i.e., AVE is equal and greater than 0.50), which is above the threshold value given by [109].

Table 7. Reliability and validity results.

Construct	Items	Loadings	Composite Reliability (CR)	Average Variance Extracted (AVE)
Adoption cost	AC1	0.726	0.853	0.661
	AC2	0.902		
	AC3	0.802		
Competitive pressure	CP1	0.734	0.868	0.571
	CP2	0.761		
	CP3	0.843		
	CP4	0.810		
	CP5	0.607		
Firm performance	FP1	0.721	0.896	0.593
	FP2	0.860		
	FP3	0.870		
	FP4	0.642		
	FP5	0.846		
	FP6	0.644		
Government support	GS1	0.904	0.90	0.75
	GS3	0.801		
	GS4	0.890		
Top management support	TMS2	0.966	0.978	0.937
	TMS3	0.973		
	TMS4	0.966		
Use of e-commerce	UEC1	0.848	0.898	0.608
	UEC2	0.880		
	UEC3	0.892		
	UEC4	0.839		
	UEC5	0.408		
	UEC6	0.697		

4.4.2. Discriminate Validity

The square root of AVE given by [110] defines discriminating validity. Furthermore, ref. [110] propose that the value of the AVE square root should be greater than the latent variables, which indicates a discriminating value. Table 8 revealed that all the diagonal values are greater than the other latent variable values. Likewise, the second criterion is to measure the validity of the constructs provided by [111,112], including the two commonly used parameters with the cutoff points HTMT.85 and HTMT.90, respectively, to evaluate the HTMT values. The values shown in Table 9 are less than the threshold values.

Table 8. Discriminate validity matrix.

	Adoption Cost	Competitive Pressure	Firm Performance	Government Support	Top Management Support	Use of E-Commerce
Adoption cost	0.813					
Competitive pressure	0.114	0.755				
Firm performance	0.010	0.364	0.770			
Government support	−0.063	0.018	−0.023	0.866		
Top management support	0.003	0.132	0.666	0.011	0.968	
Use of E-commerce	0.087	0.567	0.759	−0.040	0.426	0.779

Table 9. Heterotrait-monotrait ratio of correlations (HTMT).

	Adoption Cost	Competitive Pressure	Firm Performance	Government Support	Top Management Support	Use of E-Commerce
Adoption cost						
Competitive pressure	0.140					
Firm performance	0.053	0.422				
Government support	0.071	0.039	0.049			
Top management support	0.053	0.156	0.821	0.040		
Use of E-commerce	0.100	0.709	0.836	0.056	0.458	

4.5. Structure Model

After the measurement model, the next move was towards the structural model assessment. As discussed by [108], inner modeling is given in a structural model by considering path coefficients and t-values of direct and indirect relationships. In addition, ref. [113] suggested that the t-value should be greater than 1.64 to decide the significance relationship and further used in decision-making on the above-proposed hypotheses. Below Figure 4 shows the structure model of the study.

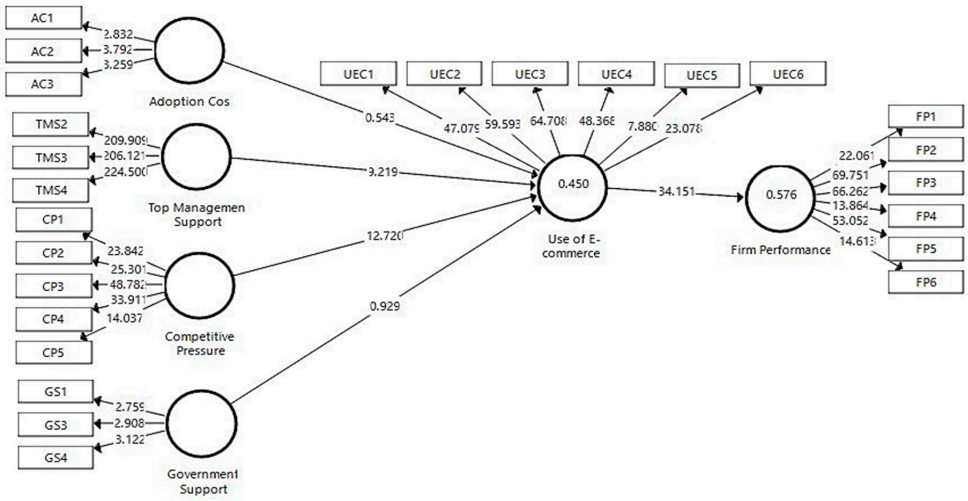

Figure 4. Assessment of structure model.

4.5.1. Assessment of Structural Model

Providently, Table 10 shows the hypotheses supported in the present study to have a t-value greater than 1.64. Therefore, three (03) out of the five (05) direct relationship hypotheses were supported in the current study. The first direct hypothesis is not supported, i.e., the direct impact from adoption cost (AC) to use of e-commerce (UEC) is not negatively significant (beta value = 0.023; T = 0.543; $p > 0.05$). Likewise, the result demonstrates that the second direct hypothesis, which is, top management support (TMS) has a significant positive impact on the use of e-commerce (UEC) (beta = 0.358; T = 9.219; $p < 0.05$), supported. Similarly, the third direct relationship, which is government support, has a significant direct impact on e-commerce (beta = −0.051; T = 0.929; $p > 0.05$), not supported. Fourth direct relationship, i.e., competitive pressure (CP) has a significant positive effect on the use of e-commerce (UEC) (beta = 0.517; T = 12.72; $p < 0.05$), and therefore, supported. Lastly, the fifth direct hypothesis is supported, as the use of e-commerce has a positive direct impact on firm performance (B = 0.759; T = 34.15; $p < 0.05$).

Table 10. Hypotheses testing results (direct effect).

Relationship	Std. Beta	Std. Error	T Values	*p* Values	2.50%	97.50%	Decision	R^2	f^2	Q^2
AC → UEC	0.023	0.043	0.543	0.587	−0.126	0.082	Not Supported	0.576	0.001	0.331
TMS → UEC	0.358	0.039	9.219	0.000	0.281	0.433	Supported	0.450	0.229	0.258
GS → UEC	−0.051	0.055	0.929	0.353	−0.123	0.098	Not Supported		0.005	
CP → UEC	0.517	0.041	12.72	0.000	0.435	0.595	Supported		0.471	
UEC → FP	0.759	0.022	34.15	0.000	0.708	0.798	Supported		0.360	

Note: AC = adoption cost, TMS = top management support, GS = government support, CP = competitive pressure, UEC = use of e-commerce, FP = firm performance.

4.5.2. Assessment of Coefficient of Determination (R^2), Effect Size (f^2), and Predictive Relevance (R^2)

The coefficient of determination (R^2) describes the degree of variation caused by all exogenous variables in the endogenous variable. In addition, ref. [109] presented the threshold values for the

appropriate coefficient of determination values as 0.75, 0.50 as moderate, and 0.25 as a weak degree. The values displayed in Table 10 predicted that the coefficient of determination has moderate levels of predictive accuracy. After R^2, the study investigated the effect size is to determine the influence of omitted exogenous variables on latent endogenous variables. In particular, it implies the difference in (R^2) between the key effects in the model under review after the removal or presence of any specific exogenous variable [114]. To measure the effect size of a specific model, the threshold values range from 0.02, 0.15, and 0.35 for no, medium, and high effect sizes. The current study showed no and medium effect size of the studied model. Likewise, the acceptance level of predictive relevance (Q^2) above 0 indicates that exogenous variables have predictive significance for the model's endogenous variables [109]. Thus, it can be found in Table 10 that both the Q^2 = 0.331 and Q^2 = 0.258 values are greater than zero. Therefore, the current research model has sufficiently predictive relevance.

4.6. Mediation Analysis

The study also examined the indirect effects of independent variables through mediation. For mediation, several tests will be used to calculate mediation, such as the Sobel test by [115] and bootstrapping, which is given by [116], employed to calculate the indirect effect of a latent variable. Moreover, as recommended by [105], the bootstrapping technique is more appropriate for small sample size and works for multivariate models. Therefore, the current study employed bootstrapping (5000 subsamples) to calculate the indirect effect of the use of e-commerce.

Consequently, Table 11 presented that the mediation (indirect effect) of adoption cost with beta = 0.018 and t-value of 0.541 does not support the mediating effect of the use of e-commerce with firm performance. Similarly, the mediation of the use of e-commerce in relationship with government support is also not significant mediation with beta = −0.039 and a t-value of 0.929. However, the indirect effect with beta = 0.272 and t-value of 8.177 is explained as significant mediation with top management support and firm performance. Lastly, the mediation effect of the use of e-commerce with competitive pressure and firm performance is also supported with beta = 0.393 and a t-value of 12.955.

Table 11. Mediation results.

Relationship	Std. Beta	Std. Error	t-Values	*p* Values	2.50%	0.97%	Decision
AC → UEC → FP	0.018	0.033	0.541	0.588	−0.094	0.062	Not supported
CP → UEC → FP	0.393	0.030	12.955	0.000	0.331	0.450	Supported
GS → UEC →FP	−0.039	0.042	0.926	0.355	−0.095	0.074	Not supported
TMS → UEC → FP	0.272	0.033	8.177	0.000	0.207	0.338	Supported

Note: AC = adoption cost, TMS = top management support, GS = government support, CP = competitive pressure, UEC = use of e-commerce, FP = firm performance.

5. Discussion

The study integrated the use of e-commerce innovation with SMEs' performance. The two aspects of the TOE model were successfully implemented. Therefore, the first contribution was the implementation in conjunction with the TOE model and technology usage (DOI theory), particularly the mediation of the use of e-commerce. The study demonstrates that two aspects of the TOE model, i.e., the organizational and environmental context factors, are essential to implement the technology usage. The study also provided a theoretical structure for manufacturing SMEs in Pakistan using the resource-based view (RBV). A total of nine (09) hypotheses were identified and formulated based on the research objectives and underlying issues. To test the theories, the statistical analysis was performed using SPSS v 25 and PLS-SEM 3.3.2. The present study analysis and findings showed that out of nine (09) hypotheses, five (05) hypotheses have a significant impact on the use of e-commerce and firm performance.

The findings specify that a firm can benefit from using an open innovation process through the use of e-commerce platforms. As suggested by [117], customer and supplier interaction are highly important for open innovation. Though, a combination of the organizational and external environment with firm innovation can enhance manufacturing SMEs' global outreach.

The results revealed that top management support (TMS) and competitive pressure (CP) is playing a significant role in the usage of e-commerce in Pakistani SMEs, and findings are consistent with the previous studies [29,32,96,118,119]. Thus, the present study considers the use of e-commerce as a strategic decision to improve Pakistani SMEs' overall performance. Further, the direct effect of e-commerce is also significant and consistent with past research [120,121]. The top management has the authority to allocate the financial and other resources needed to use e-commerce. The success of open innovation implementation is linked with the enthusiasm and support of top management to make strategic alliances and collaboration with global firms. Further, open innovation requires inter and intra-firm collaboration; therefore, SMEs need consistent leadership skills and efforts to ensure open innovation and firm growth.

Moreover, according to RBV theory, Barney [122] emphasized that firms should have unique resources and capabilities to bring towards competition in the industry to get a competitive advantage. Many studies have found consistent results with technology-enabled innovation and firm performance [123]. Further, the firms can achieve a competitive advantage if an enterprise bundles their resources and capabilities to become difficult for their competitors to imitate [124]. Moreover, some companies are focused on a full open innovation approach. At the same time, others are relying on close innovation. However, open innovation, like the use of e-commerce, is a continuous process that served as a capability towards a competitive advantage.

However, the present study analysis suggests that there is no support for the impact of adoption cost on the use of e-commerce. In contrast, cost remains one of the major barriers in literature in the adoption of technology [125]. The results revealed that the cost of adoption has an insignificant connection to the use of e-commerce. The reasoning behind the point out that the cost of human capital (e.g., training & development), the re-engineering costs of the company's structure, and the cost of failure in the manufacturing production line [126,127] are more essential considerations for technology usage rather than adoption cost. Further, the adoption cost factor does not influence the use of e-commerce in SMEs. As stated in the literature, open innovation collaborates and supports unused resources with other firms [128]. Likewise, with open innovation application, small and medium enterprises (SMEs) move towards a commission model such as third-party cloud platforms. In addition, the subscription to these e-commerce platforms is easy and cost-effective. Therefore, adoption cost does not find an influencing factor for the use of e-commerce in SMEs of Pakistan.

Moreover, the effect of government support (GS) on the use of e-commerce also has no significant relationship in the present study. Because the developing countries' government pushes and supports the adoption of e-commerce for large organizations in the following three ways. First, by providing incentives, second, by making specific policies and laws, creating skilled workers, and providing IT infrastructure [129,130]. Literature suggests that SMEs cannot pursue open innovation to commercialize its product to the global market without government support. Compared to large firms, SMEs require appropriate government policies and funding such as tax incentives, regulatory structure to avoid hacking and fraud, and e-commerce platforms to enhance open innovation in Pakistani manufacturing SMEs.

5.1. A Holistic Comparison of Our Findings with Other Studies

Prior scholars are focused mainly on two streams. First, determining factors of information communication technology (ICT) adoption [131]. Second, the usage of Innovation technology [132]. In literature, a lack of debate on e-commerce technology usage with firm performance. For instance, ref. [133] does not point out the link between sustainability and competitive capabilities in terms of environmental regulations and organizational drivers. Moreover, in the domain of technology innovation adoption, the researchers focused on one particular industry and context [134]. However, a firm's engagement in technology adoption is more concerned with community pressure and the economic risk of developing countries' enterprises [131]. Moreover, technology adoption studies are more towards adoption drivers, specifically [135]. The current study leads adoption to one step forward from innovation to performance effect. The previous research has also taken the use of sales revenue as the only performance indicator [81].

However, the current paper focused on financial as well as non-financial performance indicators. Past researchers are focused on the overall population of one sector, like the retail industry [136]. The present paper has employed four categories of manufacturing SMEs: textile, leather, sports, and surgical by applying a stratified proportionate random sampling technique.

5.2. Implications of the Study

Nonetheless, very few studies have investigated the theories of the TOE, DOI, and RBV as a combined theoretical consideration. Moreover, the study contributes by introducing the role of the use of e-commerce as a mediating variable between TOE factors and firm performance. The introduction and usage of e-commerce is key to enhancing efficiency during the era of digitalization. This study has a practical implication by using the TOE model, which is vivacious for the use of e-commerce, which ultimately leads to improved performance of Pakistani small and medium businesses. Moreover, the significant direct and indirect relationship with the use of e-commerce also calls upon the SME managers' attention towards the availability of such resources (independent variables) before implementing e-commerce in their organizations. Hence, this study has tried to explain the essential underlying factors and capabilities to convert the firm from the traditional way of doing business to click and mortar using e-commerce.

5.3. Limitations and Future Research Recommendations

The present research respondents belong to manufacturing firms, and the study's presence is beneficial only to small and medium-sized firms in developing countries. To increase the generalizability of the research, the study should have carried out through manufacturing SMEs in low-income countries around the globe. Future work should also fit the theoretical basis of dynamic capability theory by considering internal and external dynamic resources to achieve a competitive advantage.

5.4. Conclusions

The practice to implement the use of e-commerce in this era of digitization is indispensable and is of the essence during the progression of modern time. Based on technological and environmental specific factors in Pakistani manufacturing firms' context, this study is vivacious for e-commerce usage. The implementation of e-commerce will contribute to the upsurge in Pakistani manufacturing SMEs' performance in the long run. The present study contributes by providing useful guidelines for the policymakers, government regulators, and top management. These sets of bodies make a successful effort to target implementing the e-commerce usage in Pakistani manufacturing SMEs.

The research findings suggest that academic researchers and practitioners look at underlying resources and capabilities related to organizational and environmental factors before implanting e-commerce usage. Moreover, instead of motivating firms to use e-commerce only because other market players are doing so, the author has reached the point that enterprises should have a clear purpose before deciding to use e-commerce. It should align with the firms' strategy and objectives.

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The Role of Multi-Actor Engagement

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Abstract: This study aims to meet the theoretical needs in answering the problem of the role of the marketing function on the dynamic capability that involves the role of multi actors through engagement. In particular, the study discusses the capabilities of SMEs' business strategy in the offline to online market. The population of this research are owners, managers, and owners and managers of SMEs in Indonesia. The results of this study indicate that the integration of the supply chain into engagement can address the problem of the role of the marketing function that connects marketing and operations. Supply chain engagement is also able to moderate employee engagement to dynamic marketing engagement but not significantly moderate customer engagement. Meanwhile, the basis of integration as a dynamic capability in market knowledge has a significant effect on the multi-actor engagement consisting of customer engagement, employee engagement, and supply chain engagement. Summary statement of contribution: Our research builds on the three elements of multi-actor engagement that are significant against dynamic marketing engagement. The main finding of this research is that the concept of novelty can answer the proposition with the result that dynamic marketing engagement can improve business performance.

Keywords: market knowledge; multi-actor engagement; dynamic marketing engagement; business performance

1. Introduction

Knowledge is the key marketing strategy for micro, small, and medium enterprises to enter, understand, utilize, and reach the place in the hearts of customers. Therefore, it requires attitudes and behaviors that have skills in increasing networks/friendships to create or exploit opportunity from a competitive market [1]. The basis of the existence of a product that the customer may demand is derived from the application and management of knowledge in the planning arrangements related to the circulation of raw materials and finished materials, processes and production, distribution services, and the transparency of liabilities and business assets. Market knowledge management capability is the competence and modern business asset that SMEs must have in maintaining competitiveness [2].

Market knowledge is a source of competitive advantage and a concept that can be measured for its influence on company performance [3,4]. Integrating market knowledge into marketing capabilities can help companies grow [3]. To implement and develop these goals requires a reputation in designing the market knowledge system [5]. In order to generate high quality market knowledge that can serve as an intermediary bridge, it requires the support of information technology to provide learning in capturing signals from knowledge providers [6,7]. The study of Hou and Chien [2] exploring the impact of market knowledge management competencies on performance through "dynamic capabilities" finds a positive relationship between dynamic capabilities, market knowledge

management competencies, and business performance. The dynamic capabilities in marketing perspectives, according to Barrales-Molina, Martínez-López, & Gázquez-Abad [8], today become one of the significant problems with the role of the marketing function in the development of dynamic capabilities so that it is necessary to collaborate on marketing and operations to integrate market knowledge into the supply chain. It is therefore necessary for the participation of middle managers in the planning process to identify potential business and relevant supply chains to become informed in marketing strategy decisions [9].

Research on the dynamic marketing capabilities from Barrales-Molina et al. [8] still rarely analyzes the effects of dynamic marketing capabilities on strategic variables of a company, such as performance or (sustainable) competitive advantage. While in a dynamic global market, the role of internal and external functions of the company is needed in the process of creating product value that is difficult to imitate by competitors as a competitive advantage [10]. Different capabilities of resource quality and value characteristics inherent in high performing products are the company's goal to grow an existing market share and win the competition [11]. According to Hollebeek, Srivastava, and Chen [12], in today's rapidly growing marketplace, the organization's agility in responding (or ideally, getting around) changing customer-driven trends is the key to competitive success [13]. Kumar and Pansari [14] focus on understanding internal (employee) and external (customer) engagement as organizational stakeholders and found that the level of engagement can be improved by identifying the current level of internal (employee) and external (customer) engagement and applying to relevant strategies.

Meanwhile, in strategic management research based on microfoundations, the value of co-creation is viewed in the context of a service ecosystem involving the role of actors' attachment. It indicates the need to explore attachments not only as customer engagement but also the acumen of other actors, such as from suppliers, manufacturers, retailers, and providers [15]. According to Finsterwalder [16], to understand and build multi-actor engagement requires the use of item measurements and the appropriate scale to assess the degree of engagement of each actor in the focus of the interaction, whether to the perpetrator or other objects, such as resources, or both as the focus of sustainable value creation activities. According to Frow, Nenonen, Payne, and Storbacka [17], sustainable creation benefits include improved employee integration of supply chain integrity, while from a customer perspective, interaction with a company enables sustainable creation of the consumption experience, enhances customer brand experience, and rewards for strengthening relationships. Meanwhile, Grönroos and Helle [18] argue that business engagement is established on mutually beneficial calculations of benefits, and Marcos-cuevas, Nätti, Palo, and Baumann [19] argue that sustainable creation practices and capabilities are reinforced by mutual ends together widely in the mind (i.e., goals). Additionally, they also argue for continuous engagement in expanding the scope and nature of the collaborative effort (i.e., engagement) to create value in a shared sphere where the actors involved operate over time (i.e., sustainability). It can be interpreted that engagement and sustainability is about the company's ability to establish relationships with employees, supply chains, and customers [20,21]. Thus, engagement and sustainability is about a relationship in creating shared value. While in view of Ranjan & Read [22], relationships are defined as engagement, network, lasting exchange, interdependence, and collaboration, and they are a mutual, reciprocal, and recurring process that are the basis of the relationship between customers and objects in an active communication environment and/or attachment. The linkage is reinforced by Karagouni and Protogerou [21], who suggest that research both in the perspective of dynamic ability and sustainable value creation, highlights the role of capabilities that enable firms to engage in value creation activities, while dynamic ability can be considered as a facilitator in the process of sustainable value creation. Meanwhile, research on the role of capability in view of microfoundations by Pérez-Cabañero, Cruz-Ros, and González-Cruz [23] explains that marketing ability is a strategy part of the dynamic capabilities embedded in the business management process [4].

Based on these explanations, it can be stated that the dynamic marketing engagement study has two solid foundations. First, that the context of dynamic marketing ability has a relationship

with internal and external engagement as a process of competitive advantage. Second, there is a need to include the engagement of internal and external sources of the company as a source of knowledge information from a continuously growing and sustainable market [8,15,24]. To follow up these needs into this research, it is necessary to discuss the capacity gap from several studies related to dynamic capability and internal/external engagement to the company's business performance. These differences will be described in the research gap and are interpreted with an SME business perspective. According to Hou and Chien [2], market knowledge has become a major asset of modern business and the key to maintaining competitiveness. The study of Dietmar, Jaeger, and Staubmann [25] also explains that product-related export/service capabilities, partner relationship capabilities, and relationship process capabilities can replace resource shortages. In contrast to Park and Kim's [26] research explaining the type of strategy and market maturity affecting the level of dynamic capabilities, those obtained from the environment (such as customer types and technological regimes) have no relationship to dynamic levels of ability. As with Anabel Fernández-Mesa, Alegre-Vidal, Chiva-Gómez, & Gutiérrez-Gracia [27], the organization's learning capabilities are needed to improve product innovation through the intermediate of design management capabilities. This is useful for the business performance of a customer-oriented company, as the effect of market intervention can improve company performance [28]. In addition, adaptability, absorptive capacity, and corporate innovation are essential in establishing relationships in competitive markets to achieve higher performance [29].

Meanwhile, in Wilhelm's research, Wilhelm, Schlömer, and Maurer [30] state that dynamic capabilities have different performance effects in dynamic environments, especially when dynamic capabilities increase the effectiveness of operational routines at both the (high and low) levels of the dynamic environment. However, when the cost of increased efficiency is taken into account, the dynamic environment makes a difference, where the ability in a low dynamic environment indicates a smaller value because it does not impact the efficiency of the operating routine, whereas in high dynamic environments, it leads to higher efficiency of operating routines. It is crucial in developing SMEs that survive using resource-based views efficiently to transform dynamic capabilities into a key driver of SME success. Therefore, the SME strategy for managing the environment of public concern should be green business, while the ability and resources of the organization have an important role to improve the business performance of the company [31]. To fill this research gap, the authors refer to the SME industry using two offline marketing systems and online. The reference is due to the low market knowledge that SMEs have to effectively use the marketing system side by side between offline and online. Although basically, SMEs have started to use the internet marketing system, such as the use of social media, as an easy and practical marketing medium, but that is still not maximized. This is based on the focus of marketing that still relies on physical appearance and that is most still trusted by the customer in assessing the product and ease in the payment process. One study linking dynamic capabilities with social media and performance was performed by Saavedra, Andreu, and Criado [32] of 191 various sectoral companies in Spain who found evidence of the intensity effects of moderating social media marketing on the strength of relationships and the importance of strong and committed marketing strategies in an online social network for each type of business. In Indonesia, social media used by SMEs is still at the stage of following the social trend in developing communication. Although not realized, SMEs have felt the new market and the opportunity to reach customers by entering the online marketing system. The SMEs' lack of understanding is not based on online marketing learning knowledge and they are still reluctant to integrate marketing from online systems to online. This may be due to the inability or absence of coordination within the SME organization. According to Zhang and Wu [33], the ability to sense is the company's unique ability to scan and track by exploring markets and technologies. Essentially, the ability to feel is useful for realizing the company's potential to develop new products and enhance the company's competitiveness in the face of rapid environmental change.

2. Materials and Methods

In addition to online marketing learning knowledge factors and the inability to integrate marketing from offline to online systems, business phenomena are also a way of viewing angles to see company performance. The more tight the business competition, the more open the opportunities and threats that arise. Polmasari [34] reported in possore.com that the phenomenon of the development of the digital commerce or e-commerce market is currently in line with government programs and activities in encouraging SMEs, especially export-oriented ones, to grow. The research results of the Indonesian E-commerce Association (idEA), Google Indonesia, and Taylor Nelson Sofres show that in 2013 the value of the Indonesian e-commerce market reached USD 8 billion (IDR 94.5 trillion). Based on data from the Ministry of Cooperatives and Small and Medium Enterprises, the number of SMEs in Indonesia in 2013 amounted to 57,895,721 units (99.99%), contributing to GDP (constant price) of USD 1,536,918.8 billion (57.56%) and absorbing manpower of 114,144,082 people (96.99%) (Data of Micro, Small, Medium Enterprises and Large Enterprises (UB) Year 2012–2013, 2013). Meanwhile, in the report of Wardhana [35], based on data from the Ministry of Cooperatives and Small and Medium Enterprises until 2013, there are 55 to 56 million SMEs in Indonesia and only about 75 thousand to 100 thousand who have a website (site). Similarly, Deloitte 2015 reports that 36% of SMEs in Indonesia are still offline, 37% have only very basic online capabilities, 18% have intermediate online capabilities, and 9% have advanced online business capabilities with e-commerce capabilities.

The data clearly affirm the vital role of small and medium enterprises in Indonesia in realizing national goals to create jobs, improve living standards, and international competitiveness, which is why this digital requirement is an important agenda for the Indonesian government. From the results of the research, SMEs using digital technology can increase revenues by up to 80% or be 17 times more likely to be innovative and ready to compete internationally, and one and a half times more likely to increase employment. Therefore, government intervention in increasing broadband access to help SMEs become digital businesses, expanding e-payments, investment access, and e-government services is very influential.

The description of secondary data shows the phenomenon of the development of the digital SME industry in general and also indicates the existence of a marketing business phenomenon in the digital system. Therefore, learning is needed in integrating business into the online marketing system and the importance of coordination within the organization to equip the knowledge of the SME market as a basis for dynamic capability in order to survive and compete in a competitive market environment. Based on the background, research gaps, and business phenomena that occur in the world of digital SME industry, it is necessary to explore a research model that connects dynamic marketing capabilities with business performance on digital SMEs. Therefore, the research problem is formulated as follows: "How to build a SME marketing strategy in an offline system through a new theoretical approach to overcome the research gap in dynamic ability and performance". Furthermore, from the essence of synthesis theory and a literature study is proposed a new concept of dynamic marketing involvement derived from dynamic capability; a market knowledge strategy that engages customers, employees, and the supply chain for competitive advantage. Then, from the synthesis process produces a proposition that is:

> *"Dynamic marketing capabilities and multi-actor involvement as a competitive advantage strategy of a company on the concept of dynamic marketing engagement has the potential to improve the company's business performance".*

The population to be researched is the owners, managers, or owners and managers of SME businesses marketing with two marketing systems, from offline to online, in Indonesian SMEs, spread over 7 (seven) sub-districts, specifically in the trade and industry centers of SMEs in Indonesia [36,37]. This research develops basic theoretical models and empiric research models to explain how business performance is improved, as shown in Figure 1. The research model was developed by reviewing previous research on the relationship of the variables, so that nine hypotheses

were built. Data came from as many as 250 questionnaires that were distributed and as many as 249 questionnaires were re-processed. The analysis tool used was structural equation modeling (SEM) with SPSS.AMOS software.

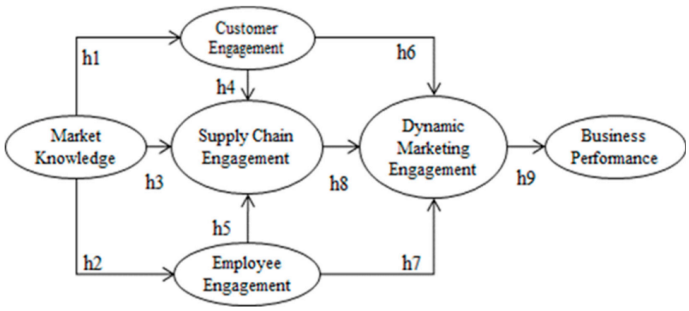

Figure 1. The empirical research model.

3. Results

The results of statistical tests on the research model show the value of the goodness of fit index, among others, and chi-square, probability, Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), The Minimum Sample Discrepancy Function Divided with degree of Freedom (CMIN/DF), Tucker Lewis Index (TLI), and Comparative Fit Index (CFI) indicate that it has a decent value as indicated because it has the expected range value by the indicator used, so it is feasible to test the hypothesis, presented as follows in Table 1.

Table 1. Assessment of the goodness of fit research model.

Goodness of Fit Index	Cut off Value	Results	Model Valuation
Chi-Square	Expected small	412.484	Fit
Probability	≤0.05	0.055	
GFI	0.90 ≤ GFI < 1	0.872	Marginal Fit
RMSEA	≤0.08	0.026	Close Fit
RMR	≤0.05	0.136	Bad Fit
TLI	0.95 ≤ TLI < 1	0.982	Good Fit
NFI	0.90 ≤ NFI < 1	0.866	Marginal Fit
AGFI	0.90 ≤ AGFI < 1	0.849	Marginal Fit
RFI	0.90 ≤ RFI < 1	0.853	Marginal Fit
CFI	0.95 ≤ CFI < 1	0.983	Good Fit
IFI	0.90 ≤ IFI < 1	0.984	Good Fit
Normed Chi-Square	2.0	1.121	Good Fit

The result of hypothesis testing shows empirical evidence from nine hypotheses submitted that are all accepted, and presented as follows in Table 2.

Table 2. Hypothesis testing.

			Estimate	S.E.	C.R.	*p*	Label
Customer Engagement	≤	Market Knowledge	0.419	0.103	4.068	***	Sig
Employee Engagement	≤	Market Knowledge	0.616	0.126	4.888	***	Sig
Supply Chain Engagement	≤	Market Knowledge	0.307	0.127	2.41	0.016	Sig
Supply Chain Engagement	≤	Customer Engagement	0.316	0.102	3.117	0.002	Sig
Supply Chain Engagement	≤	Employee Engagement	0.369	0.085	4.348	***	Sig
Dynamic Marketing Engagement	≤	Customer Engagement	0.213	0.1	2.12	0.034	Sig
Dynamic Marketing Engagement	≤	Employee Engagement	0.197	0.086	2.286	0.022	Sig
Dynamic Marketing Engagement	≤	Supply Chain Engagement	0.224	0.096	2.336	0.02	Sig
Business Performance	≤	Dynamic Marketing Engagement	0.158	0.078	2.02	0.043	Sig

Note: *** indicate significance at 1% respectively. Source: Author's calculation.

Hypothesis 1 (H1). *Market Knowledge positively affects Customer Engagement.*

The testing parameter of the influence of Market Knowledge on Customer Engagement shows the result of the estimated value of 0.419, the value of c.r. is 4.068 > 2.0, and the probability value is 0.000 > 0.05. It can be concluded statistically that the variable Knowledge Market proved to have a positive effect on Customer Engagement. This result is the same as developed by Cui and Wu [38] in that Market Knowledge established with Customer Engagement in joint development has a significant impact on the design of the organization. The findings are also consistent with the findings of Chien and Chen [39], Lau [40], and Abdolmaleki and Ahmadian [41] who discovered Market Knowledge with significant new product development on Customer Engagement.

Hypothesis 2 (H2). *Market Knowledge positively affects Employee Engagement.*

The influence of Market Knowledge on Employee Engagement shows an estimated value of 0.616, a C.R. value of 4.888 > 2.0, and a probability value of 0.000 < 0.05. It can be concluded statistically that the variable of Market Knowledge proved to have positive effect on Employee Engagement. These results are the same as those found by Ye, Marinova, and Singh [42] and Yang Chen, Tang, Jin, Li, and Paille [43]. The findings of Chen, Wang, Huang, and Shen [44] show market linking ability is considered to be an important ability that must take into account the firm's engagement in service innovation that requires integration of employees.

Hypothesis 3 (H3). *Market Knowledge positively affects Supply Chain Engagement.*

The effect of Market Knowledge on Supply Chain Engagement shows the result of the estimated value of 0.307, the value of C.R. of 2.410 > 2.0, and the probability value 0.016 < 0.05. It can be concluded statistically that the variable of Market Knowledge proved to positively influence Supply Chain Engagement. The results are the same as the findings of Feng and Wang [45] and Kanapathy, Khong, and Dekkers [46]. Likewise, Feng and Zhao's [47] findings suggest market knowledge in relationships with suppliers has a positive influence with supplier engagement.

Hypothesis 4 (H4). *Customer Engagement positively affects Supply Chain Engagement.*

The influence of Customer Engagement on Supply Chain Engagement shows the result of the estimated value of 0.316, the value of C.R. is 3.117 > 2.0, and the probability value is 0.002 < 0.05. It can be concluded statistically that the variable of Customer Engagement proved to have a positive effect on Supply Chain Engagement. These results are the same as those developed by Kannan and Choon Tan [48] and Singh and Power [49], likewise with the findings of Danese and Romano [50] and He, Keung Lai, Sun, and Chen [51]. The findings of Siew-Phaik, Downe, and Sambasivan [52] also state the alliance's strategic alliance motives (suppliers, producers, and customers) have a positive relationship with the level of interdependence.

Hypothesis 5 (H5). *Employee Engagement positively affects Supply Chain Engagement.*

The influence of Employee Engagement on Supply Chain Engagement shows the result of the estimated value of 0.369, the value of C.R. of 4.348 > 2.0, and the probability value 0.000 < 0.05. It can be concluded statistically that Employee Engagement variables proved to positively affect Supply Chain Engagement. These results are the same as those developed by Vanichchinchai [53] and Huo, Han, Chen, and Zhao [54]. Similarly, Alfalla-Luque, Marin-Garcia, and Medina-Lopez [55] found that the relationship between employee commitment and operational performance is fully mediated by supply chain integration, which finds significant Employee Engagement to Supply Chain Engagement.

Hypothesis 6 (H6). *Customer Engagement positively affects Dynamic Marketing Engagement.*

The influence of Customer Engagement on Dynamic Marketing Engagement shows the result of an estimated value equal to 0.213, value of C.R. equal to 2.120 > 2.0, and probability value 0.034 < 0.05. Then, it can be concluded statistically that the Customer Engagement variable proved to have a positive effect on Dynamic Marketing Engagement. These results are the same as those developed by Agarwal and Selen [56]. According to Anabel Fernández-Mesa et al. [27] in their findings, there is a positive relationship between dynamic capabilities in design management and product innovation performance. While Gu, Jiang, and Wang [57] found that customer feedback and networking have a positive impact on high-tech SMEs' innovation performance.

Hypothesis 7 (H7). *Employee Engagement positively affects Dynamic Marketing Engagement.*

The influence of Customer Engagement on Dynamic Marketing Engagement shows a result of an estimated value equal to 0.197, value of C.R. equal to 2.286 > 2.0, and probability value 0.022 < 0.05. It can be concluded statistically that Employee Engagement variables proved to have a positive effect on Dynamic Marketing Engagement. These results are the same as those developed by Saxena and Srivastava [58], but in contrast to the findings of Román and Rodríguez [59], that the effect of technology used as a result of the salesperson's performance is entirely mediated by qualified skills of salespeople and customer sales. Likewise, the results of Tsai's [60] study found that empowered employees had a direct impact on the commercialization performance mediated by dynamic marketing capabilities.

Hypothesis 8 (H8). *Supply Chain Engagement positively affects Dynamic Marketing Engagement.*

The influence of Supply Chain Engagement on Dynamic Marketing Engagement shows a result of an estimated value equal to 0.224, value of C.R. equal to 2.336 > 2.0, and probability value 0.020 < 0.05. It can be concluded statistically that the variable of Supply Chain Engagement proved to have a positive effect on Dynamic Marketing Engagement. These results are the same as those developed by Chang [61], and Lee and Rha [62] provide an explanation for companies and the supply chain to understand the impact of different conditions and define scenarios for applying varied market situations. Similarly, the view of Chiu and Kremer [63], which suggests the scenario of supply chain centralization benefits the time performance of supply chain networks, while supply chain centralized scenarios show superiority to cost performance. Unlike Day, Lichtenstein, and Samouel [64], routines—results of supply management capabilities formed from a consistently internal set of routines—were significantly related to financial performance mediated by operational performance.

Hypothesis 9 (H9). *Dynamic Marketing Engagement positively affects Business Performance.*

The influence of Dynamic Marketing Engagement on Business Performance shows an estimated value of 0.158, a value of C.R. of 2.020 > 2.0, and a probability value of 0.043 < 0.05. It can be concluded statistically that the Dynamic Marketing Engagement variable proved to have a positive effect on Business Performance. These results are the same as those developed by Wilden and Gudergan [65], Swoboda and Olejnik [66], and Zhang, Xue, and Dhaliwal [67], who argue that IT-based static value judgments are critical for a company to achieve success and build relationships, and use electronics to interact with customers, suppliers, and other partners in the supply chain to offer new opportunities in developing dynamic capabilities with joint creation.

4. Discussion

The testing of the role of supply chain constraints as mediators bridging the variables of customer engagement and employee engagement to dynamic marketing attachments is essential to provide answers to significant gaps in marketing function roles [8]. According to Suhardi [68], a variable

is said to be a mediator because it plays a role to influence the change of independent variables (independent variable) to other variables (response variable, dependent variable). Meanwhile, according to Baron and Kenny [69], a variable is called a mediator if the variable affects the relationship between predictor (independent) and criterion (dependent) variables. Ghozali [70] argues that the determination of intervening variables depends on their theoretical form. In this study, the theoretical model of the supply chain supplier variable becomes the mediator variable and for testing, the Sobel test is done to assess the significance of direct or mediation influence in the structural equation model [71]. The Sobel test calculation results show that the role of the supply chain variable has less role to play between the customer engagement variable and dynamic marketing engagement, where the value $Z = 1.863 < 1.98$ and the p-value is 0.062, above the 0.05 significance. With these results it can be stated that the supply chain engagement variable has not been able to mediate between customer engagement variables with dynamic marketing engagement. While the role of the supply chain variable is significant to be the mediator between the employee engagement variable and dynamic marketing engagement, where the value of $Z = 2.055 > 1.98$ and the p-value of 0.039 is under the 0.05 significance. With this result it can be stated that the supply chain engagement variable can be a mediator between the employee engagement variable and dynamic marketing engagement.

The results of direct influence calculations show that the supply chain dependency variable (0.240) has a greater direct impact than employee engagement (0.214) and customer engagement (0.186) to dynamic marketing engagement. The result of the indirect effect calculation shows that the market knowledge variable (0.289) has a larger indirect effect than employee engagement (0.090) and customer engagement (0.062) to dynamic marketing engagement. Meanwhile, for business performance improvement, the indirect effect of employee engagement (0.051) is greater than market knowledge (0.048), customer engagement (0.041), and supply chain engagement (0.040). Additionally, the result of the calculation of total influence shows the employee engagement variable (0.304) has greater total influence than the engagement of market knowledge (0.289), customer engagement (0.248), and supply chain engagement (0.240) to dynamic marketing engagement. Meanwhile, for business performance improvement, the total effect of dynamic marketing engagement (0.166) is greater than employee engagement (0.051), market knowledge (0.048), customer engagement (0.041), and supply chain engagement (0.040).

The main purpose of this research was to build basic and empirical theoretical models in connecting the research gap between dynamic capability and actors' engagement to business performance as embodied in the new concept of dynamic marketing engagement.

Theoretically, dynamic marketing engagement is a new concept through a process of decline from the concept of dynamic marketing capabilities and the concept of engagement associated with competitive advantage and sustainability competitiveness. The basic foundation of novelty is based on the incorporation of dynamic capabilities and marketing capabilities, while the process involves the role of employees, customers, and the supply chain as the multi-actors' engagement to enter and play the role of marketing function in two non-digital and market interconnections. Theoretical concepts are derived from two combinations of theoretical views; first, the dynamic capability theory (DC) concept of Teece, Pisano, and Shuen [72] and the emergence of a new paradigm called dynamic marketing capabilities (DMCs), which Barrales-Molina et al. [8] uncovered. The emergence of the term DMCs poses significant problems to the role of the marketing function that requires the collaboration of marketing and operations. Second; development of engagement theory proposed by Kumar and Pansari [14] for competitive excellence through engagement still requires re-measurement of the role of employee and customer engagement to performance, and the last is the phenomenon of the business of the emergence of social media as a marketing tool in the online marketplace.

Based on the above description, theoretically the views above have a critical space that requires a new concept to answer those needs. According to Barney, Jr, and Wright [73], one of the implications of maturity of a critically stated theory lies in the moment followed by revitalization or decline. Thus, it can be concluded that the concept of dynamic marketing engagement as a novelty has qualified.

Empirically, the research gap used in building the concept of dynamic marketing engagement is based on Dietmar et al.'s [25] studies, which suggest that product-related export/service capabilities, partner relationship capabilities, and relationship process capabilities can replace resource shortages. This is in contrast to Park and Kim's [26] research, which explains that this type of strategy and market maturity affects the level of dynamic capability but has no relationship with dynamic ability levels. Meanwhile, Wilhelm et al. [30] stated that dynamic capabilities have different performance effects in dynamic environments.

The empirical results of the concept of dynamic marketing engagement through nine hypothetical pathways proved significant to business performance. Interpretation of SEM analysis results through SPSS.AMOS 22 on direct, indirect, and total influence suggests that dynamic marketing incremental variables play a greater role in improving business performance. In addition, to run the concept of a dynamic marketing engagement strategy that is directly more influenced by supply chain engagement and indirectly influenced by market knowledge and totally influenced by employee engagement.

5. Conclusions

The research issue of "how to build a marketing strategy for SMEs in an offline system with a dynamic engagement strategy to improve business performance" refers to some contradictions. First, to answer the role of marketing functions on dynamic capabilities in facilitating service logic; second, the relationship of market knowledge, the engagement of actors, and business performance; third, the phenomenon of business marketing in the digital system. Referring to the research problem that has been formulated, it can be concluded based on the results of the hypothesis that first, dynamic ability can answer the role of the marketing function in business operations through supply chain engagement and facilitate service logic through customer and employee engagement to dynamic marketing engagement. Second, the relationship of market knowledge to the engagement of actors (customers, employees, supply chains) positively impacts business performance through dynamic marketing engagement. Third, the phenomenon of SME marketing business in the digital system has proven positive that using digital technology can increase sales. Thus, it can be expressed that dynamic marketing engagement strategy can improve business performance of SMEs. To run a dynamic marketing engagement strategy requires direct collaboration with the supply chain, has strong market knowledge, and total employee roles in understanding the customer's desire to achieve sustainable competitive advantage.

The propositions developed in this study are based on the dynamic ability theory of management innovation innovated by Teece et al. [72] as the dynamic marketing capabilities (DMCs) term of Barrales-Molina et al. [8] and the service logic theoretical views expressed by Vargo and Lusch [74] contained in the research of Kumar and Pansari [14]. The dynamic capability's view explains that dynamic capability is a company's ability to integrate, build, and configure internal and external competencies to cope with rapidly changing environments. Meanwhile, the service-dominant logic view (S-D Logic) suggests service is a fundamental goal of economic activity and marketing. The theoretical contribution in the study of marketing management through propositions developed is that, firstly, dynamic marketing capability proved positive to the concept of dynamic marketing engagement. Secondly, the multi-actor engagement proved positive against the concept of dynamic marketing engagement. Thirdly, dynamic marketing engagement proved positive for business performance.

Based on the conclusion of the research problem and the results of the hypotheses, it can be concluded that "dynamic marketing capabilities and multi-actor involvement as a competitive firm strategy of the company on the concept of dynamic marketing engagement proved positively to improve the company's business performance". The findings are in line with Hou and Chien [2], exploring the impact of market knowledge management competencies on performance through "dynamic capabilities". The findings also addressed the problem of dynamic ability in marketing perspectives through the integration of the supply chain into the multi-actor attachment, which Barrales-Molina et al. [8] argued was one of the significant problems with the role of marketing functions in the development of dynamic capabilities. With the integration of the supply chain into

the concept of attachment, the findings answer Chandler & Lusch's [15] statement about the need to explore attachments not only as customer engagement, but also the actor's other acumen from suppliers, manufacturers, retailers, and providers. The findings are also in line with Kumar and Pansari [14], who find the level of engagement can be improved by identifying current levels of internal (employee) and external (customer) engagement and applying to relevant strategies.

The findings also dispose of the multi-actor engagement in line with the definition of actors' attitudes defined by Storbacka et al. [24], as the same disposition with actors for attachment, and activity of engagement in the process of interactive integration of resources within the service ecosystem. The novelty findings of the dynamic marketing engagement concept as a management innovation strategy in marketing service activities for sustainable competitive advantage in improving the performance of SME's business is in accordance with the theory of dynamic capability and service logic that is in line with Karagouni and Protogerou's [21] opinion that dynamic capability theory facilitates logic service.

The limitations of this study related to the process and the results of the study are described as follows: (1) The relationship between the variables built in the empirical model still yields a marginal relationship so it is necessary to re-examine the indicators that affect the significance and the fit of the model; likewise, with research samples that limit the generalization of the study so that it needs to be differentiated and added. (2) The concept of dynamic marketing engagement still leaves a difference where Park and Kim's [26] (dated) discovery finds that market strategy and maturity from customers and technology has no relationship with dynamic levels. However, it is in line with the findings of Anabel Fernández-Mesa et al. [27], which suggest that corporate innovation is necessary in establishing relationships in competitive markets to achieve higher performance [29]. Additionally, research finds dynamic capability in a high dynamic environment leads to higher efficiency of operating routines. The findings are also consistent with the findings of Alfalla-Luque et al. [55], in that the relationship between employee commitment and operational performance is fully mediated by supply chain integration.

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Article

Innovative CRM and Performance of SMEs: The Moderating Role of Relational Capital

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Abstract: Customer Relationship Management (CRM) is more than an information tool and plays a critical role in small and medium enterprises (SMEs). The present study explored the moderating effect of relational capital (RC) on the relationship between CRM dimensions and the performance of 284 Yemeni manufacturing SMEs. Partial Least Squares-Structural Equation Modelling (PLS-SEM) was used to test the study's hypotheses. Results indicate that only three of the CRM dimensions have a significant effect on performance. The moderating effects of relational capital on this relationship were also examined and were found to be significant for only two CRM dimensions: technology-based CRM and CRM organization. Key customer focus and CRM knowledge management had no effect. The findings of this study offer important insights for owners and managers of SMEs, researchers, and policymakers to further understand the effects of relational capital and CRM on SMEs' performance. SMEs should be encouraged to develop their CRM and relational capital to improve their performance.

Keywords: customer relationship management (CRM); relational capital (RC); Yemeni SMEs; performance

1. Introduction

CRM is an enterprise approach that understands and impacts customer behaviour through effective interactions with them for the purpose of enhancing customer attraction, retention, loyalty and, ultimately, customer profitability [1–3]. CRM is important for top management to deliver the vision and CRM strategy to their employees [4,5].

This interaction between the organization and its employees is also important to ensure the CRM process can be successful in achieving the objectives and enhancing organizational performance [1,6]. The success of CRM implementation can increase customer satisfaction and the retaining ratio and also increase employee satisfaction and subsequently improve company performance [7,8].

In addition, several quantitative studies on CRM have explored its function and influence in specific sectors in developed countries. However, it remains to examine and confirm the applicability of the concept of CRM specifically in manufacturing industries and in developing countries [9,10]. Emerging markets may exhibit different characteristics.

In another scenario, SMEs are major participants in economic development in both advanced and developing countries and are at the centre of growth in both [11,12]. They encourage economic growth by providing employment opportunities for rural and urban people, enabling flexibility and enhancing innovative practices through entrepreneurship, and increasing international trade through diversification of economic activities. Their role in income generation and the economic growth of developing countries is especially important [13–16].

According to Al Montaser [17], the Yemeni economy largely consists of small and medium enterprises, with SMEs accounting for 20.9% of the country's manufacturing sector [18]. Meanwhile, in Kuwait, 90% of the private employment is attributed to SMEs, and in Egypt SMEs constitute over 95% [19]. Generally speaking, the data from the Arab countries show that SMEs account for 90% of the total firms. In fact, the majority of countries around the globe reported that SMEs provide 40–80% of employment. SMEs contribute significantly to GDP; for example, 59% in Palestine, 77% in Algeria, and 25% in Saudi Arabia [20].

Yemen is one of the least-developed nations in the region, and the unemployment rate reached 12.81% in 2019 [21]. It is important to note that SMEs perform a crucial function in the economies of all countries by making jobs available and acting as suppliers for larger enterprises. From a survey conducted in 2018, SMEs in Yemen were considered as the solution to economic problems such as worsening unemployment and poverty among the population [22,23].

In addition, there is little literature on integrated models for the performance of Yemeni manufacturing SMEs [18,24–27] found that existing studies do not provide adequate inputs into the development of a common global understanding of CRM outcomes [28–31] argued that a well-integrated framework for developing a CRM model through empirical studies and research is still needed, and four dimensions of CRM have been identified: CRM organization (CRMO), key customer focus (KCF), technology-based CRM (TCM), and CRM knowledge management (KM). However, an integrated mechanism to show how CRM leads to performance outcomes remains an unresolved problem, and further studies are required. According to meta-analyses conducted by Madhovi and Dhliwayo, [32] and Nam, Lee and Lee [33] the relationship between CRM and performance is robust, although others have found only negative implications [27,34–36]. Results suggest that additional moderators should be assessed in future studies.

A few studies on relational capital in Yemeni and Arab manufacturing industries do exist; for example, Sharabati, Jawad and Bontis [37] explored a broad domain of firm- or industry-specific processes pertinent to RC, although their findings remain disconnected [38]. In the field of human resources, various suggestions for creating and validating a new theoretical model have been proposed [39,40]. Meanwhile, several authors remain sceptical about the function, nature, and role of the RC concept [39].

However, there is limited evidence on how the impact of CRM dimensions on SMEs' performance is affected by relational capital in Middle Eastern countries. This study aims to examine the joint influence of CRM dimensions and relational capital on SEMs' performance in Yemen. It concentrates on two questions:

Research Question 1. *How do CRM dimensions impact SMEs' performance*?

Research Question 2. *How does RC moderate these relationships*?

Finally, the findings of this study will be useful to policymakers, researchers, and managers. In particular, they provide current knowledge of the effect of CRM dimensions, RC and SMEs' performance, contributing to the literature on performance and the firm-based view.

2. Research Objectives

The research objectives are developed from the research questions, as follows:

1. To examine the relationship between the CRM dimensions (TCM, KM, CRMO and KCF) and the performance of Yemen's SMEs.
2. To examine the moderating effect of relational capital on the relationship between CRM dimensions (TCM, KM, CRMO and KCF) and the performance of Yemen's SMEs.

3. Literature Review

3.1. CRM and Performance

Technology has been found to enhance long-term relationships with customers if customer data is utilized efficiently. More specifically, customer data can be obtained at different points, mainly when a contact is made with the customer, such as the point-of-sale, customer service interaction, and during their inquiries [40]. The main objective of the CRM technological solution is to track, capture, and analyze customers' interactions and transactions over time [41].

In line with the above discussion, CRM technology is a key factor which influences SMEs and leads to superiority over competitors. To achieve better performance, enterprises should pay attention to markets and customers [29,42]. CRM is also a useful tool to assist an enterprise in enhancing its relationship with customers and in attaining higher performance [43]. CRM technology is information technology that is deployed for better management of customer relationships [44,45]. It includes front-office applications that may support sales, marketing and services, and data storage, as well as back-office applications that may integrate and analyze data about customers.

Abdullateef, Mokhtar and Yusoff [46] and Chang, Park and Chaiy [47] found a significant relationship between technology-based CRM and performance. According to [48], previous studies have discussed the impact of technology on CRM projects through its capability in collecting, analyzing, storing, and sharing both potential and current customers' information in ways that greatly enhance employees' ability in responding to the needs and requests of individual customers, therefore leading to better ways of attracting and retaining customers [43,49,50].

However, technology-based CRM systems result in an increase in process, product, marketing, and administrative activities and service organizations' capabilities [51]. The organization should have inbuilt mechanisms for customer management systems, customer satisfaction tracking, and a proper reward system. The entire organization consists of the people, process, and technology, and in CRM all are harmonized to provide superior customer satisfaction and develop profitable relationships. Based on previous studies, the present study hypothesizes as follows:

Hypothesis 1a (H1a). *There is a significant relationship between key customer focus and manufacturing SME performance in Yemen.*

Hypothesis 1b (H1b). *There is a significant relationship between CRM organization and manufacturing SME performance in Yemen.*

Hypothesis 1c (H1c). *There is a significant relationship between CRM knowledge management and manufacturing SME performance in Yemen.*

Hypothesis 1d (H1d). *There is a significant relationship between technology-based CRM and manufacturing SME performance in Yemen.*

3.2. The Moderation Effect of RC

Relational capital (RC) refers to the ability of an organization to interact with a wide range of external stakeholders (such as customers, suppliers, competitors, and trade and industry associations) as well as the knowledge embedded in these relationships [52]. In business and marketing research, RC has increasingly become a significant area of study [53,54] described it as a major type of capital that supports competitive advantage. However, the majority of organizations suffer from the opportunistic actions of their partners that lead to increased transaction costs.

In addition, several studies indicate that customers' collaboration may lead to enhanced product development efficiency and reduced new product launch time [55,56]. New product development

requires customer participation to provide and test innovative ideas and to create successful products in SMEs [57,58].

Following a similar line of argument, collaboration with suppliers can furnish invaluable information concerning new or alternative technologies that positively affect product/process innovation [59–61], the level of product novelty [62] and the turnover produced from products that are new and enhanced [52]. Viewed from the relational capital perspective, SMEs need to obtain knowledge from customers and develop relational capital with ease. Knowledge from customers in terms of their associations and connections is also invaluable for optimal performance.

The moderation influence indicates that the moderator variable may weaken or strengthen the relationship between the independent and dependent variables [63]. The possible moderating effect of RC on the relationship between the variables and performance is supported by the literature [64]. Relational capital refers to the ability of an organization to interact with a wide range of external stakeholders (such as customers, suppliers, competitors, and trade and industry associations) as well as the knowledge embedded in these relationships [38].

Kamukama [65] referred to RC as the value of a company's external relationships with the organizations and individuals with whom it does business. It is knowledge embedded in the marketing channels and customer relationships that an organization develops through the course of conducting business [66–69]. In the same way, [70] identified RC as an intangible asset that is based on developing, nurturing and maintaining high-quality relationships with any organization, individual, or group that influences its business position in the market.

As mentioned above, RC can play an important role as a moderator variable. For instance, Muhammad [64] investigated this relationship and suggested a moderating effect of relational capital on factors affecting performance. Previous studies have also examined the relationship between CRM and performance [27,34–36], but with different results and lack of consistency.

In addition, many studies which examined the CRM and performance relationship have led to polemic results between significant relationships [44,67] or not significant relationships [35,68]. Accordingly, moderator variables are typically added where results show differences in weak or strong relationships between a foreteller and a norm variable; this clears the values of the circumstances that weaken or strengthen the relationship [63]. It is appropriate to add a moderating variable in order to resolve the inconsistent findings concerning the relationship between CRM and SME performance. Based on the discussion above, the present study hypothesizes the impact of relational capital as follows:

Hypothesis 2a (H2a). *Relational capital moderates the relationship between key customer focus and manufacturing SME performance in Yemen.*

Hypothesis 2b (H2b). *Relational capital moderates the relationship between CRM organization and manufacturing SME performance in Yemen.*

Hypothesis 2c (H2c). *Relational capital moderates the relationship between CRM knowledge management and manufacturing SME performance in Yemen.*

Hypothesis 2d (H2d). *Relational capital moderates the relationship between technology-based CRM and manufacturing SME performance in Yemen.*

The theoretical framework of the current study there is one independent variables, namely, CRM; one moderating variable, namely, relational capital; and one dependent variable, namely, SME performance, as shown in Figure 1.

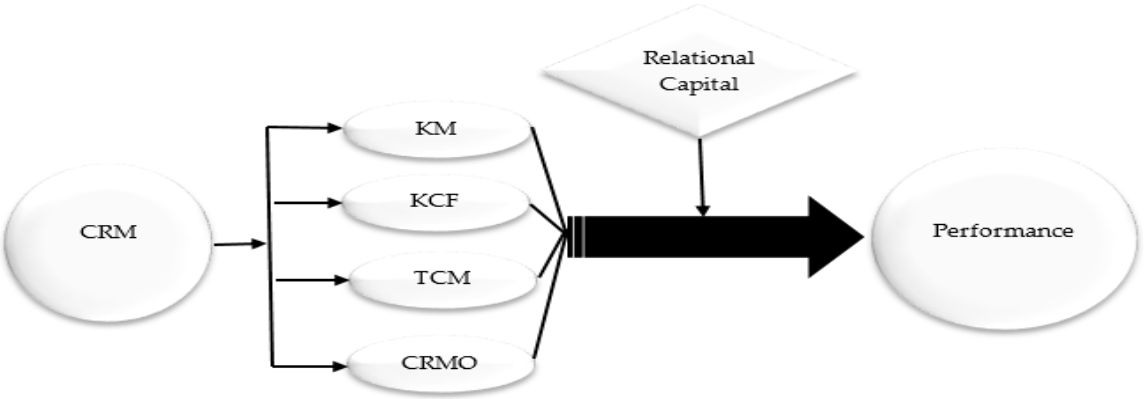

Figure 1. The study framework.

4. Research Method

4.1. Study Population

The present study employs a sampling method to obtain data and make inferences from the whole target population. The study's target population is Yemeni manufacturing SMEs. The study's population frame is taken from the 2017 Directory of Small and Medium Manufacturing Companies [18] that currently lists 1441 manufacturers.

4.2. Sampling Size

From the total of 1441 SMEs, the sample size table of Krejcie and Morgan [71] was applied; as the population increases, the sample size increases at a diminishing rate and remains constant at 307 when the population is between 1400 and 1500. For this study, to ensure the minimum response number of 307 cases, and taking into account that the survey method has a poor response rate, a total of 475 questionnaires was distributed to owners. This took into consideration that the larger the study sample, the more the results can be generalized to the target population. The selected sampling method enables the gathering of accurate information from the population concerning CRM, RC, and performance [72].

4.3. Sampling Technique

This study employed the stratified random sampling design, where the population was divided into sub-groups/strata prior to obtaining random samples from each stratum proportional to the population. The participants of each stratum have specific attributes and characteristics. The stratification was conducted because it is an efficient sampling design and is suitable in cases when different information is obtained from different strata in one single population pool [73].

This choice was made because of the different structure and management of the two types of enterprises (small and medium) [74]. More specifically, in proportionate stratified random sampling, the size of the sample of each stratum should be proportional to the stratum population when related to the whole population. Stratification provides more information for a given sample size [73].

The simple random sampling technique is popular as each member of the population has an equal and independent chance of being selected [75]. Following the use of proportionate stratified sampling to select the number of firms for each category of SME, random sampling was used to select the final sample. The complete list of SMEs was entered in SPSS and a random number list generated which was finally used for administering the questionnaires.

4.4. Data Collection Procedures

Primary data was collected from the owners of Yemeni manufacturing SMEs using a survey questionnaire. The administration of the questionnaire copies must be effective and organized in order

to heighten the response rate [76], and as such, self-administration of the questionnaire was adopted, where responses were recorded on a numerical scale.

In addition, questionnaire administration calls for the consideration of several measures to improve the response rate, and this is quite significant as a low rate of response could lead to biased or un generalizable findings [77]. The response rate is described as the percentage of respondents that return the questionnaires, while the quality of responses is the level of data completeness and usefulness.

Sekaran and Bougie [73] presented different procedures for delivering a questionnaire in order to increase the level of the respondents' interest, and these include the questionnaire's attractiveness, precision, and professionalism. In addition, complex wording and long sentences must be avoided, with the items conforming to the scope and objectives of the study. A 20-day period was provided to the respondents for questionnaire completion, after which non-response was followed by visits, reminders, and phone calls to maximize the rate of response [78].

All 475 firms in the sample were approached and the questionnaire was self-administered, with details as reported above. The researcher established a connection with the firms to sort out any ambiguities and to increase the rate of response. Data was collected over a 5-month period from all the sample units.

4.5. Response Rate

A total of 307 completed copies of the questionnaire were collected from the respondents over a period of five months and the screening exercise was completed after that. Although the researcher was asked to double-check completed copies of the questionnaire in case of missing data, 23 out of the 307 responses were discovered to have some problems and were not utilized for this study, leaving a total of 284 responses for analysis. Table 1 shows us the response rate. Table 1 summarizes the study sampling:

Table 1. Questionnaire response rate.

Total Questionnaires Administered	**475**
Total non-response	168
Total number of questionnaires returned	307
Unusable responses *	23
Usable responses	284

Note: * Unusable responses were because of missing/suspicious data.

4.6. Measures

CRM: Measures of CRM were developed based on the research of Sin et al., [43] and comprised 17 items; *RC*: The 10 items that measured relational capital are mainly based on the scales of Bontis, Sharabati and Jawad [37]; *Performance*: This study measured a firm's performance using 10 items based on the research of Mokhtar, Yusoff and Ahmad, Kaplan and Norton and Gupta and Govindarajan [79–81]. See Appendix A. Responses were made on a 5-point scale ranging from 1, strongly disagree, to 5, strongly agree.

4.7. Analysis and Results

Partial least-squares analysis (PLS-SEM) was used to examine the study framework because it is suitable for the sample size [82]. It was used to estimate the measurement and structural models [83]. A bootstrapping assessment was used to examine the significance of the constructs' factor loadings in the measurement model and structural model [82].

4.7.1. Measurement Model

The study employed Cronbach's α and composite reliability to estimate the reliability of the study variables; they ranged from 0.703 to 0.865 and from 0.807 to 0.894, respectively. Based on the suggestion

of Fornell and Larcker [84], this study also conducted an assessment of the discriminant validity with the help of AVE; the correlations among the latent constructs were compared with the square roots of AVE [84]. Discriminant validity was also confirmed through Voorhees, Brady, Calantone and Ramirez's [85] criterion, where indicator loadings are compared with other reflective indicators in the cross-loading table.

In other words, first, discriminant validity was confirmed using Fornell and Larcker's [84] condition, with an AVE of 0.5 or above. Then, the square root of the AVE should exceed the correlations among the latent variables.

Following the composite reliability procedure, all the indicators with different loadings were taken into account and interpreted, similar to Cronbach's alpha coefficients. Regardless of which particular reliability coefficient is used, internal consistency exceeding 0.70 is considered as satisfactory for an adequate model. On the other hand, values lower than 0.60 are an indicator of lack of reliability. The rule of thumb provided by Hair et al. [82] for the interpretation of the composite reliability coefficient is that the value for a specific construct has to be 0.70 or above; it is evident that the values range from 0.807 to 0.914, indicating sufficient internal consistency reliability of the measures. The measurement model's full estimates are presented in Figure 2.

In addition to the above, discriminant validity was confirmed by conducting a comparison between the indicator loadings with cross-loadings as recommended by Henseler, Ringle and Sarstedt [86]. They explained that to achieve sufficient discriminant validity, the indicator loadings have to be higher than the cross-loadings; Table 2 presents this comparison, with all the indicator loadings higher than the cross-loadings, indicating sufficient discriminant validity.

Although Fornell-Larcker's method has been utilized for over thirty years, it is still subject to weakness in its poor sensitivity in light of evaluating discriminant validity, calling for a suitable alternative. In particular, the method's weakness lies in the lack of theoretical explanations, notwithstanding the significant correlations of specific items that should be realized with their constructs as well as the weak correlations with other constructs. The method fails to offer empirical evidence on the false correlation via theoretical unrelated indicators and constructs. Finally, the approach offers a criterion value rather than a statistical test [86]. Table 3 presents the Fornell-Larcker criterion of this study.

In response to this issue, the heterotrait-monotrait (HTMT) ratio was introduced for the estimation of the correlation among constructs [86]. It is applicable as a practical criterion by comparing it with a pre-identified threshold, where HTMT values higher than the pre-identified threshold show a paucity in discriminant validity for the latent variables that are compared. The accurate pre-identified threshold is debatable in that some authors suggest a value of 0.85, while others selected 0.90 [86]. Table 4 presents the HTMT ratio of the variables of this study.

Table 2. Loadings and cross-loadings.

	CRM	KCF	KM	PEF	RC	TCM
CRMO1	0.791	0.314	0.585	0.392	0.112	0.133
CRMO2	0.798	0.339	0.522	0.279	0.151	0.512
CRMO3	0.679	0.469	0.461	0.343	0.087	0.563
CRMO4	0.846	0.364	0.464	0.438	0.158	0.528
CRMO5	0.740	0.348	0.239	0.364	0.183	0.462
KCF1	0.322	0.780	0.171	0.585	0.259	0.529
KCF2	0.382	0.776	0.232	0.522	0.237	0.479
KCF3	0.406	0.712	0.159	0.528	0.237	0.503
KCF4	0.373	0.737	0.102	0.543	0.068	0.452
KM1	0.279	0.101	0.646	0.027	0.028	0.098
KM2	0.362	0.189	0.848	0.049	0.035	0.182
KM3	0.167	0.158	0.714	0.034	0.214	0.251
KM4	0.377	0.183	0.644	0.018	0.341	0.187
PEF1	0.219	0.259	0.046	0.698	0.182	0.543
PEF3	0.318	0.035	0.034	0.744	0.279	0.028
PEF4	0.346	0.214	0.021	0.773	0.343	0.049
PEF5	0.414	0.341	0.068	0.777	0.291	0.134
PEF6	0.239	0.035	0.028	0.668	0.134	0.459
PEF7	0.123	0.214	0.035	0.726	0.224	0.511
PEF8	0.123	0.039	0.214	0.633	0.249	0.469
PEF9	0.431	0.335	0.039	0.711	0.247	0.364
RC1	0.302	0.392	0.335	0.249	0.691	0.585
RC2	0.309	0.279	0.392	0.155	0.752	0.522
RC3	0.469	0.315	0.279	0.321	0.783	0.528
RC4	0.197	0.301	0.343	0.519	0.765	0.482
RC6	0.117	0.489	0.438	0.145	0.652	0.323
RC7	0.128	0.461	0.353	0.191	0.670	0.245
RC8	0.016	0.399	0.347	0.191	0.699	0.105
RC10	0.148	0.133	0.446	0.452	0.629	0.074
TCM1	0.340	0.516	0.102	0.326	0.257	0.785
TCM2	0.446	0.563	0.186	0.077	0.354	0.822
TCM3	0.102	0.528	0.184	0.492	0.297	0.779
TCM4	0.186	0.462	0.167	0.489	0.358	0.777

Table 3. The Fornell-Larcker criterion.

	CRM	KCF	KM	PEF	RC	TCM
CRM	0.763					
KCF	0.439	0.746				
KM	0.318	0.220	0.709			
PEF	0.414	0.639	0.053	0.722		
RC	0.179	0.314	0.485	0.339	0.703	
TCM	0.372	0.653	0.218	0.617	0.375	0.793

Table 4. The Heterotrait Monotrait Ratio (HTMT).

	CRMO	KCF	KM	PEF	RC	TCM
CRMO						
KCF	0.628					
KM	0.493	0.246				
PEF	0.528	0.793	0.084			
RC	0.229	0.319	0.628	0.397		
TCM	0.681	0.809	0.259	0.719	0.413	

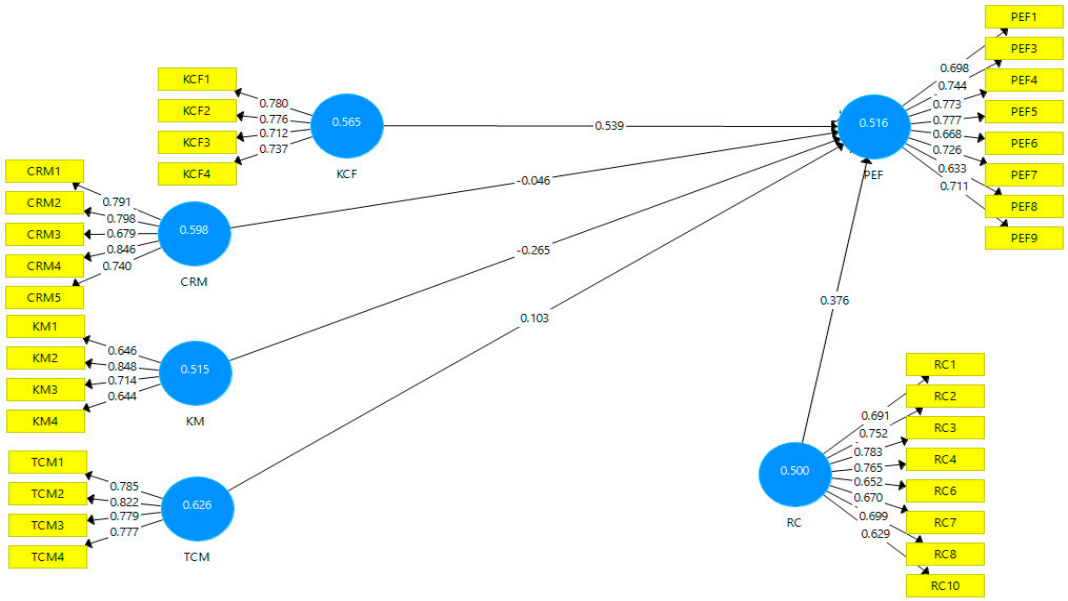

Figure 2. Assessment of the measurement model.

4.7.2. Assessment of Significance of the Structural Model

Following the determination of the measurement model's validity, the structural model was assessed using a standard bootstrapping procedure, with 500 bootstrap samples and 284 cases to determine the significance of the path coefficients. This was conducted according to the guidelines established by [82]. The structural model's full estimates are presented in Figure 3 and Table 5.

Table 5. The structural model (Direct).

	Std. Beta	Std. Dev	*t*-Values	*p*-Values	Decision
KCF -> PEF	0.523	0.105	9.067	0.001	Supported
CRMO -> PEF	−0.036	0.108	0.443	0.614	Not Supported
KM -> PEF	−0.341	0.091	3.152	0.004	Supported
TCM -> PEF	0.209	0.074	1.656	0.041	Supported

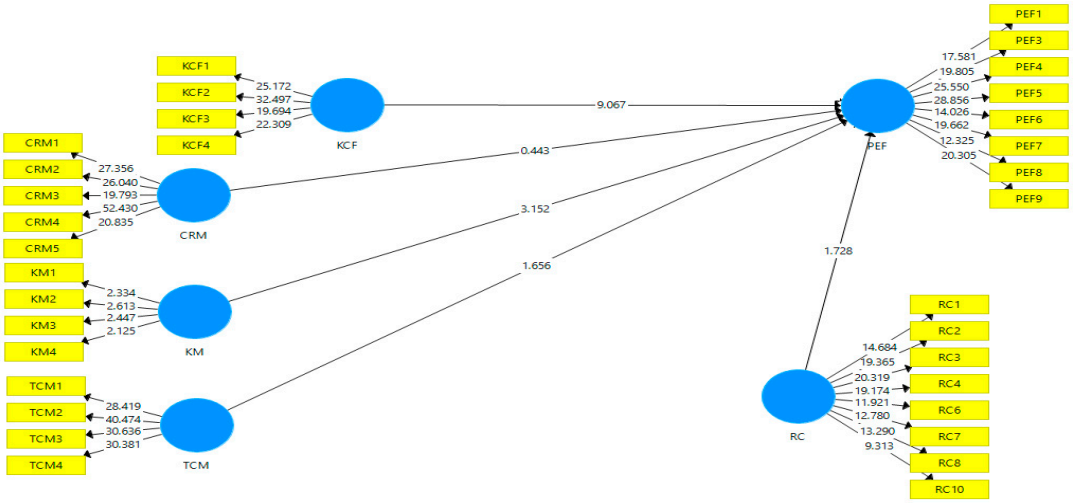

Figure 3. The structural model.

The direct relationships in the model of this study were examined through the PLS structural model and the findings are presented in Table 5. Results for four hypotheses can be seen in the table.

Hypothesis 1a predicted a significant association between key customer focus and performance among SMEs in Yemen. Findings from the data analysis indicate that this association is a significant positive relationship ($\beta = 0.539$, $t = 9.067$, $p < 0.001$). H1a is therefore supported, which means that key customer focus influences performance and that key customer focus is very important. H1b predicted a significant positive association between CRM organization and performance. However, this hypothesis is not supported ($\beta = -0.046$, $t = 0.443$, $p < 0.614$), meaning that among SMEs in Yemen, CRM organization was not found to significantly influence performance.

H1c predicted a significant association between CRM knowledge management and performance, and the results confirmed this ($\beta = -0.265$, $t = 3.152$, $p < 0.004$). That is, H1c is supported. H1d similarly predicted a significant positive association between technology-based CRM and performance, and this association was also supported ($\beta = 0.103$, $t = 1.656$, $p < 0.041$). This can be interpreted to mean that technology-based CRM influences performance.

Finally, PLS-SEM was applied to detect and estimate the strength of the moderating effect of relational capital on the four CRM dimensions (and the performance of SMEs. RC did not moderate the KCF-performance relationship ($\beta = -0.013$, $t = 0.230$, $p < 0.431$) or the KM-performance relationship ($\beta = 0.027$, $t = 0.667$, $p < 0.213$). However, it did moderate the TCM-performance relationship ($\beta = -0.089$, $t = 1.410$, $p < 0.040$) and the CRMO-performance relationship ($\beta = 0.284$, $t = 3.303$, $p < 0.003$). That is, H2b and H2d were supported, but H2a and H2c were not. Figure 4 presented relation capital moderation algorithm, and Table 6 enumerates the results of the estimates following the application of the product indicator approach to examine the moderating effect of relational capital on the relationship between exogenous and endogenous latent constructs.

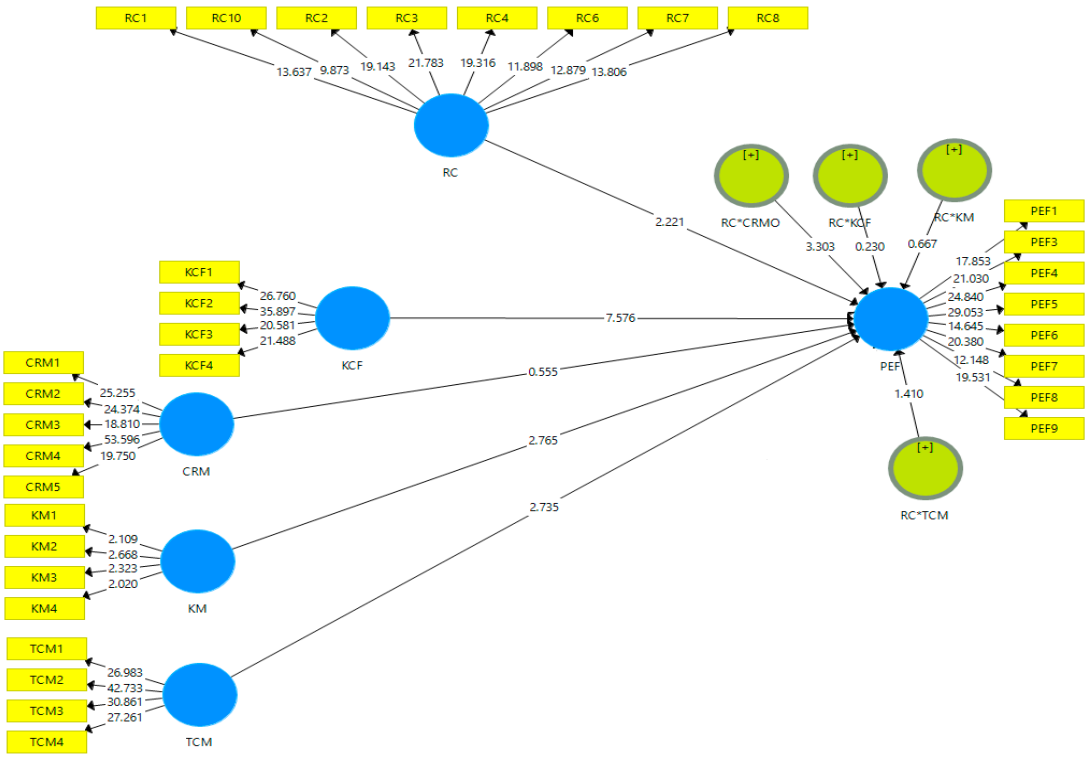

Figure 4. The relational capital moderation algorithm.

Table 6. The structural model (moderating effects).

Relationships.	Std. Beta	Std. Error	*t*-Values	*p*-Values	Decision
RC > CRMO -> PEF	−0.284	0.083	3.303	0.003	Supported
RC > KCF -> PEF	−0.018	0.056	0.230	0.431	Not Supported
RC > TCM -> PEF	−0.089	0.063	1.410	0.040	Supported
RC > KM -> PEF	0.027	0.041	0.667	0.213	Not Supported

5. Discussions: Innovative CRM, Performance and Relational Capital

The CRM process is used to explore the relationship between organizations and their customers; one tangible outcome is to increase organizations' profit by enhancing customers' purchasing behaviour in the future. For instance, it trains and guides employees in delivering high-quality products/services that are important for promoting good customer relationships [87,88].

This study used Yemeni manufacturing SMEs as the population to investigate the effect of investigating CRM on performance. Results indicate that only three dimensions of CRM (KCF, TCM and KM) have a significant effect on SMEs' performance [43,89], and that the fourth dimension (CRMO) does not [36]. The findings obviously presented the major effect paths and CRM's strength for firm performance, thus offering complete and helpful information

The study has high value for both researchers and practitioners. The findings indicate that the key factors of organizations in practising customer knowledge, effective customer performance, and customer loyalty affect CRM in SMEs in Yemen. Based on these findings, the study concludes that it is important to meet customers' needs and expectations in terms of calling, or communication via modern Internet communication. SMEs in Yemen need to provide adequate customer service to increase their performance.

Unfortunately, previous studies in Yemen, the Middle East, and the Arab world have not investigated the impact of CRM on the performance of this very important sector of the country's economy, and the relationship between CRM and manufacturing SMEs' performance had yet to be investigated. The present study has made an important contribution to the literature by investigating this important construct in line with one of the objectives of the study.

In line with the second research question, the study investigated the moderating effect of relational capital on the relationship between CRM and SMEs' performance. RC is a complex construct which can be classified as the relation between firms and customers [37]. This concerned the direct relationship between CRM dimensions and SME performance in Yemen. However, based on the findings, this direct relationship may be influenced significantly or not significantly and may be improved or reduced depending on the relational capital of the firm. In other words, relational capital moderates the relationship between CRM and manufacturing firm performance. The implication of this finding is that organizations with a higher level of relational capital perform better. This moderating effect is an important contribution to the literature, as previous studies have only focused on the direct relationship [51,90,91].

The literature review found mixed results from studies of CRM and performance; these include studies by [35,36]. Based on these inconsistent findings, this study found it appropriate to introduce a moderating variable in the relationship between CRM and SME performance; it contributes by examining RC's moderating role in the CRM dimensions relationship with the performance of SMEs in Yemen.

Indeed, to answer the research questions, we formulated the hypotheses. The result of the moderation test for the effect of relational capital on the relationship between CRM dimensions and performance indicated that relational capital significantly moderates the relationship between two CRM dimensions and performance: TCM and CRMO; it does not moderate the relationship between key customer focus and CRM knowledge management and SMEs' performance. This is in line with previous studies; Akroush et al., [27] argued that key customer focus has an insignificant and negative relationship with organizational performance. Others studies have found mixed results [36].

Reinartz, Krafft and Hoyer [35] concluded that the CRM process-performance link is not strong. Vishnu and Kumar Gupta reported a weak and negative relationship between intellectual capital and performance [47,92,93]. The findings showed that RC did not significantly influence the key customer focus and knowledge management relationships, but did significantly influence technology-based CRM and CRM-organization relationships with performance. This result may be attributed to the lack of absorptive capacity of manufacturing firms for knowledge and technologies through RC. Moreover, the cognitive gap between effective CRM dimensions and the owners of organizations when it comes to RC capabilities may also have negative effects as this gap reflects basic perceptions, interpretation, and evaluation systems that are integrated within the culture of the organization. In other words, cognitive skills and knowledge distances were not sufficient to maximize the CRM dimensions and bring about an understanding of opportunities via RC.

Finally, to sustain and survive in the rapidly changing market, SMEs have to focus on their relationships with customers and suppliers to renew their team skills to innovate radically high competences. Foltean et al., [44] explained that the exploitation of the relationship with customers emphasizes the need for employee training and resources. Agnihotri et al., [45] showed that as markets become increasingly hyper-competitive, CRM is needed as an immediate measure to create sustainable advantage. Hence, continuous organizational offers for their customers are the only effective technique for advantage-structure.

Organizations need to pay attention to innovative CRM processes, which help optimize the deployment of more tangible services, to match the quality of foreign services. Of the combined RC enable firms to proactively develop market strategies and enable innovative capabilities using a knowledge-based approach when in doubt.

6. Theoretical Contribution

This study contributes to both the CRM and firm-based view literature. First, the findings indicate that CRM significantly impacts SMEs' performance. These results are consistent with previous studies regarding the performance outcomes of CRM [44,67] and emphasize the significance of the owners in promoting CRM and business development in Yemen. This explains why Yemeni manufacturing SMEs should invest more in CRM technology to improve performance and enhance their market share. PLS-SEM analysis further reveals that two dimensions of CRM significantly affect performance indirectly via relational capital. This result provides insights into the CRM, RC, and SME performance relationship. This study clarifies that support from the firms' owners can develop performance both directly and indirectly by promoting relationships with customers and suppliers, and crystallizes the mechanisms through which CRM provides firms with several advantages affecting their plans and decisions. These findings contribute to the relational capital literature by confirming the significant roles played by CRM in enhancing SMEs' performance in Yemen.

Second, the results show that RC does not moderate the effects of two of CRM dimensions (KCF, KM) with SMEs performance. This is an interesting finding. It is also in line with the World Bank [94] report that the quality of relational capital in Yemen is under par because of poor-quality training in the local education system. This shows that employees lack skills, and this in turn affects their ability to utilize CRM to increase performance. The study findings support the World Bank's report on the low RC in Yemen. Therefore, it is expected that the findings contribute to knowledge concerning the moderating effect of RC on the CRM-performance relationship.

7. Implications

The findings of this study have implications for government policy as well as managerial implications for managers and owners of SMEs in Yemen. The implications are not necessarily limited to Yemen, as owners/managers and government policy-makers in other developing countries may also learn from these findings.

The policy implication of the study consists of advice for the government, the Yemeni Ministry of Industry and Trade and the Yemeni Ministry of Technical Education and Vocational Training. Given the large number of manufacturing firms in Yemen, the government should pay very close attention to this sector. It a surprise that Yemeni manufacturing SMEs do not contribute much to the country's GDP. The World Bank [94] critically appraised the performance of the Yemeni economy in recent years and concluded that it has been very poor, with the manufacturing sector being especially weak. The World Bank put the blame for the low performance of the manufacturing sector on insufficient CRM to enhance the market share and revenue of SMEs in Yemen.

Therefore, the government should intervene in SME operations in Yemen so as to improve CRM and improve the relationship with the suppliers and customers in local and international markets by providing modern technology to SMEs to help them acquire modern industrial equipment and train their employees. However, based on our findings, the problem of low performance cannot be resolved without skilled human capital, which implies the need for training.

Finally, owners and managers of SMEs should reduce their emphasis on classical ways of managing organizational processes [95–97]. For example, they need to adopt new creative ideas and technologies to enhance their products, service, and operations. In addition, RC needs to be adopted in operational activities in order to achieve high performance. Owners and managers must also increase their investment in CRM activities to build good relationships with their customers and suppliers and achieve trust locally and internationally.

8. Limitations and Future Research

Since the population of the study was limited to manufacturing SMEs in Yemen, it is recommended that other sectors of the Yemeni economy be investigated, for example, performance among service businesses like banks, hospitals, airports, etc. Additionally, the respondents for this study were owners, and the analysis concentrated only on the organizational level. Therefore, a detailed analysis of study variables cannot be comprehensive at other levels such as group and individual levels. Also, the current study used a quantitative approach to achieve the study objectives, but future studies might investigate the extent of the study variables by using qualitative techniques, to provide in-depth knowledge of the issues. Finally, the moderating effect of relational capital variables was not previously recognized in the literature. Hence, this study has successfully advanced theory and understanding of the effect of CRM and performance, emphasizing the important moderating role of relational capital variables. Future researchers can use other dimensions of intellectual capital such as innovation capital or human capital.

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Appendix A. Study Measures

Table A1. Relational Capital.

Relational Capital
-Our organization is currently working on joint projects with many other organizations.
-Our organization has diverse distribution channels.
-A high ratio of the organization's business is done with strategic alliances.
-People from outside the organization are consulted when decisions are made within the company.
-Our organization prides itself on being partnership-oriented.
-Our organization has greatly reduced the time it takes to resolve a customer's problem.
-It is important for the company to share knowledge with its partners.
-Our organization gets feedback from customers under different circumstances.
-Our organization has relatively complete data about the suppliers.
-Our organization continually meets customers to find out what they want.
Performance
-Return on Investment.
-Sales Volume.
-Market Share.
-Sales Growth.
-Innovative Products.
-Profitability Growth.
-Cash Flow.
-New Product Development.
-Research and Development Activates.
-Cost Reduction Program.
CRM Dimensions
1-Key Customer Focus
-Through on-going dialogue, we work with individual key customers to customize our offerings.
-Our organization provides customized services and products to our key customers.
-Our organization makes an effort to find out what our key customers need.
-When my organization finds that customers would like a product to be modified, the departments involved make coordinated efforts to do so.
2-CRM Organization
-Our organization has the sales and marketing expertise and resources to succeed in CRM.
-Our employee training programmes are designed to develop the skills required for acquiring and deepening customer relationships.
-Our organization has established clear business goals related to customer acquisition, development, retention and reactivation.
-Employee performance is measured and rewarded based on meeting customer needs and on successfully serving the customer.
-Our organizational structure is accurately designed around our customers.
3-CRM Knowledge Management
-Our organization's employees are willing to help customers in a responsive manner.
-Our organization fully understands the needs of our key customers via knowledge learning.
-Our organization provides channels to enable on-going, two-way communication with our key customers.
-Customers can expect prompt service from employees.
4-Technology-based CRM
-Our organization has the competent technical personnel to provide technical support for the utilization of computer technology in building customer relationships.
-Our organization has the right software to serve our customers.
-Individual customer information is available at the time.
-Our organization maintains a comprehensive database of our customers.

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Article

R&D Collaboration, Competitiveness Development, and Open Innovation in R&D

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Abstract: The competitiveness of the agro-industrial sector depends not only on its specific performance but also on the character and degree of the innovation performance, vital to added value development and differentiation in the biobased value-chain. This work intends to show, how through research and development (R&D), collaboration is possible to improve agri-food companies' competitiveness, helping them to integrate biotechnology and offer innovative products. The method used to support the R&D collaboration model developed involves a diagnosis of biotechnological tools use, for developing appropriate solutions from food safety to food quality, improving health, and achieving new ingredients and/or food products within an agri-food Association partners survey results were integrated into the study of R&D collaboration practice. Results show that the companies (wine culture, fruticulture, and olive culture subsectors) inquired do not develop biotechnology research. They were all micro-business with a low volume of commercial billing, and only 27.3% claimed to have developed research activities in partnership with external research centres, but were not associated with higher education institutions. The barriers to the implementation of biotechnology techniques considered more relevant by respondents were access to capital and specialized human resources, which led to reinforcing the R&D collaboration strategy design.

Keywords: innovation; biotechnology; agri-food sector; R&D collaboration

1. Introduction

For the last 100 years, technological change has been a major factor in shaping agriculture [1]. Agriculture has been significantly affected by new ways to perform tasks, new products, and new procedures. These new elements of technological and institutional change are fundamental to increase production, improve quality, and introduce new products.

On forecasts of world population growth [2], there is a challenge of designing sophisticated and efficient methods to expand the production of food and renewable energy without diminishing natural resources. The establishment of sustainable agriculture that preserves the environment and provides food security is a primary factor of human development against climate change and the decrease of non-renewable energy resources. In fact, and as recently reviewed by Pelai et al. [3], the primary benefit of biotechnologies identified in the agriculture literature is food security.

With the discovery of recombinant DNA technology, the emergence of modern biotechnology in the 70s has resulted in a radical change in the technological and organizational pattern of all the sectors that directly or indirectly are connected to the "life sciences". Agriculture—and the entire production chain of agribusiness—is among these sectors that have been suffering from the discovery

of this new technology [4]. Biotechnology comprises numerous different research technologies or methods, and different sectors or fields of application [5].

Biotechnology finds application in the agricultural and food sector, mostly in five main levels [6]:

- The genetic modification of crops to increase the income of the agricultural industry;
- The genetic modification of crops to increase efficiency in the processing of nutrients and the manufacture of food;
- The application of enzymes and micro-organisms to food manufacturing processes;
- In the introduction of new features into final products;
- In analytical and diagnostic tools.

In the last few decades, biotechnology applied to agriculture has been mainly oriented towards the improvement of the income of holdings of agricultural products intended for the food sector; in the future, it is expected that higher growth is found to rise to a level of appreciation of the characteristics of the foods and the use of agricultural products in place of fossil raw materials in the production of energy and of polymers.

Especially in the EU (European Union), where public opinion is unreceptive to the use of biotechnology in the food industry, there is some controversy and some substantial barriers are expected to its expansion [6].

In recent years, the biotechnology sector in Portugal has experienced an essential and significant increase in the number of companies created, with currently more than 40 in Portugal, most of them created between 2001 and 2006 [7,8], and about half of them claim to have activity in the field of food. Specifically, in the food sector, companies aim to develop products or improve processes on a technological basis. However, start-up companies obtain most of the invoices with the provision of other services not directly related to biotechnology, while carrying out the research and development (R&D) or await the arrival of funding to start the work. On the demand side of traditional food sector companies in Portugal, there is a growing interest, but there are few partnerships in this regard. Some biotech companies in this sector established business relationships and product and process development with national food industries [6].

In recent years, European regions are experiencing industrial restructuring, provoking a shift from traditional manufacturing towards more modern and complex industries, like information, computing, and technology (ICT), biotechnology, and Big Pharma [9,10]. The need to achieve competitiveness through innovation created from incorporating knowledge and new ideas converted into economic activities will be the "front end of innovation" [11] (p. 671). This increased knowledge endowment, in turn, improves the entrepreneurial activity profitability by enabling recognition and engagement in new business opportunities [12–15].

In the highly competitive global market, the ability to innovate is a determinant for enterprises' success, which certainly depends on the qualification of the human resources but also of the establishment of strategic partnerships with higher education institutions (HEI) and R&D centres. The agri-food sector based on community and national policies and regulations should bet on the improvement of competitiveness through the promotion of technology transfer, modernization, innovation, and quality throughout the food chain. The agri-food industry, nowadays, in industrialized societies, started to renew the concept of the role of agriculture, assuming a new paradigm focusing on the sustainable use of natural resources, the creation of public goods, equity in access to quality foods, increasingly in delivering compelling value to society [16]. Traditions and cultural values, for example, assume a decisive role in the resource potential for the generation of value, if appropriately used by entrepreneurs. According to this model, knowledge, and development in agriculture also become a more complex and systemic concept breaking with the model of linear relations between stakeholders [17,18]. In this sense, the business has become increasingly sensitive to the opportunities for innovation, not only related to changes in technology but also related to the strategy, marketing, organization, and management [18]. Generally, the adoption of agricultural biotech innovation imposes

relationship-specific investments that exacerbate hold-up costs between biotech producers and farmers and research centres that facilitate the biotech innovation internalization. Many new actors now have a decisive role in the mechanisms of adoption of innovation [18]. This discussion might occur due to the research indicators, such as patents and technological innovation, which only count partially to measure the process properly [19] since the analyses must be restricted to patent-intensive sectors. The growth of firms is intensively related to knowledge and innovative basis and to the ability to combine different types of knowledge (for example when mixing science and technology-driven innovations with innovations based on learning through doing, using, and interacting), despite the limitation beside a particular point of investment [19,20]. Also, there is some discussion in the literature around the interaction of public policy and strategic R&D decision-making by business managers. Firms do act, and react, within a political environment and in the case of biotechnology, a highly politicized environment, but there is a range of perspectives offered which might promote the incorporation of these concerns [21].

In Portugal, as in Europe, the vast majority of enterprises are small and medium-sized (SME). The dimension of business has difficulty with the technological shift since they have not the ability to invest and create the industrial conditions of R&D to offer the added value products that consumers need and desire [22–26]. This framework is also reflected in the RIS3 (Research and Innovation Strategies for Smart Specialization) plan for the Centro region considering the relevance and diversity of its unique natural products, universally recognized in national and international markets. Also, in this plan, biotechnology appears to be a determinant tool for technological and economic innovation based on its character, sustainable nature, and technological excellence. Nevertheless, there is a low index for knowledge and technology transfer from R&D centres to companies, and a weak capacity for the industry to incorporate biotechnological innovation. This new cooperative challenge is of outmost relevance at the regional level to facilitate active collaborations between industry and research in the field of bioeconomy and to add value to natural products [27–30].

This is of utmost relevance for agro-industry due to its natural and regional products, that need to have market-products with add value to guarantee market and economic growth. Furthermore, small firms (characteristic in the agri-food sector) seldom innovate in isolation but, instead, rely heavily on external partners for information and other inputs. In fact, as an alternative to industry collaboration (a situation challenging in the agri-food sector since small firms perceive larger firms as competitors), small firms often partner with universities and R&D centres that provide them access to new knowledge and technology necessary for innovation, as well as the necessary mechanisms to integrate knowledge successfully [31,32]. In this context, the ability to enhance R&D activities supporting innovation in small agribusiness depends strongly on the partnership with local/proximity R&D centres [33] to obtain information and other inputs that are key determinants of innovation in small firms [34–38].

The HEI and the firm's relationship, in the R&D perspective, was deeply studied. The geographical proximity from firm to university and the academic research quality are also recognized as determinants for the relationship between university and businesses and their collaborative research and licensing [39]. On the other hand, businesses that are small-sized and/or in an isolated location have more difficulties in choosing a public R&D partner. Several authors suggested that the success of the partnership to be established between universities and firms rely mainly on the sector activity, size, and degree of research absorption capacity [40–44]. However, geographical proximity and the way that the agreements between the institutions are established and patents registered are crucial for relationship success [45]. There is no unique way of how HEI and business establish a fruitful relationship, but the trust of the relationship between the parts is what lead to the success of the knowledge transfer for other authors [46–48]. The different ways that this relationship may take place can be guided by two guidelines [45]: the establishment of partnerships and the experiences of innovation development within the regional smart specialization priorities. To promote national and regional development and diminish the differences in growth within the countries, engaged and developed smart specialization strategies to enhance the differentiation, economic development based on the

endogenous and national/regional assets, and therefore regions and countries could have a more sustainable economic and social development. This path was the origin of many European countries developing their strategies and regional organization, namely in the Centro Region of Portugal where a regional specialization strategy was designed (RIS3).

Agriculture still is an activity that maintains great importance in Portugal and in particular, in the region of AAPIM (Farmers association for mountain fruit integrated production, Guarda, Portugal) associates operate, Centro region of the country, but it is developed, above all, as a complement to other principal activities. The most relevant agricultural productions are vegetables, vines, olive groves (these two products representing the vast majority of the permanent crops of the territory), cereal (rye, wheat, and maize), chestnut, and some fruit-growing species (apple and pear). At the level of livestock farming, the ovine and bovine production stands out. The agricultural holdings are mostly of small dimensions (between 1 and 5 ha), and the total number of farms represent approximately 21% of the total farmland in the Centro Region of Portugal [49], a region that is the third-largest contributor to the Portuguese agriculture gross domestic product (GDP). This situation led to our geographical focus of the research.

Given the above, it seems that the introduction of innovation in the agriculture system is crucial. Because of this, we want to identify what is happening in the agricultural SMEs that have already demonstrated a sensitivity to the importance of innovation and implemented some type of technology. So, we contacted AAPIM (Farmers association for mountain fruit integrated production, Guarda, Portugal) with these main goals in mind:

- To estimate the economic scope and size of AAPIM's associates;
- To assess the characteristics and status of AAPIM's associate's innovation degree;
- To estimate the innovative behaviour and performance of AAPIM's associates;
- To identify business perceptions of barriers to collaborative R&D and opportunities.

With these research objectives, it was possible to propose a better science and technology (S&T) policy for AAPIM's associates within an R&D collaboration process, expressed in this paper. Therefore, we present the main results of the research made and its impact on the R&D activity developed in the Polytechnic Institute of Guarda, as an example of how HEI may contribute to the knowledge transfer needed for the small agribusinesses of the region.

2. Materials and Methods

The Centro Region of Portugal, where AAPIM and its associates are located, accounts for approximately 31% of Portugal's total area and 22% of the population living in the country. This region is characterized by presenting a low demographic density resulting from the existent asymmetry within the region where there are desertified "inland" areas, in contrast with the coastal lands, which are more populated, urbanized, and industrialized. This asymmetry is also reflected in the regional economy encompassing both low technology level industrial sectors (e.g., agri-food), and some medium and high-tech sectors such as health services, biotechnology, telecommunications, new materials, ICT, and renewable energies. The primary sector accounts for 3.8% of regional gross value added (GVA), and the regional industrial structure is mainly composed of SME (about 99% of total) [50]. Considering its specificities, the RIS3 of the Centro Region highlights eight thematic domains as determinants for regional innovation and economy: agroindustry, forestry, sea, tourism, ICT and electronics, materials, health and wellness, and biotechnology, to valorise and potentiate the main regional endogenous resources, adding value [51].

As a result, the Guarda Polytechnic Institute, as an HEI research centre, developed a knowledge transfer model to promote R&D collaboration with local firms, in particular, in the agri-food sector. This model, polytechnic to business (P2B), is embedded with the RIS3 guidelines and have defined four focus areas of intervention [45]: Lodging P2B (ideas and innovation development); IDT Services (Innovation and Development of Technological Services) -innovation services to answer business

challenges and development of strategic business partnerships; boxes of training (specific training courses to answer business needs); Policasulos (an incubator and accelerator centre). One of the first challenges assumed in P2B was the design of a specific R&D collaboration strategy with the regional firms in the agri-food sector. For that, this work was planned to understand and operationalize the concept of biotechnological tools, its influence on agriculture, the role of biotechnology and impact on innovation development, and business success and competitiveness, based on R&D alliances.

Data Collection

The information was collected through a survey (Appendix A) that uses the provisional statistical definition of biotechnology adopted by the different OECD (Organization for Economic Cooperation and Development) groups and measures biotechnology activities per the list-based definition [5]. The method was chosen to provide a direct and interpreting use of data since it quantifies the aspects necessary to analyse in the research, allowing us to examine relationships between variables. For that, the research design was based on descriptive research since the study's objective involves the portraying of the characteristics of the research focus and the determination of the frequency of occurrence and the degree of the association of the variables [52]. Furthermore, descriptive research is also useful to combine with the decision maker's implicit model of how strategy and marketing system function regarding biotechnology use. AAPIM carried out the data collection, so it would be possible to have more direct contact with the business companies and collect data more comprehensively. The survey is divided into sections that address farmer's associate's business, investment, revenues, R&D expenditures, and employment, as well as their innovative activities, including innovation strategies and collaborative R&D performance, were collected. Demographic and socio-cultural information, in terms of gender, age, type of degree was also analysed.

The survey was distributed, according to the method of the sample survey, using as reference the population of AAPIM business associates (n = 555). A convenience sample of AAPIM businesses companies associates was defined, with a confidence level of 95% and a confidence interval of 11%, (n = 55), considering the number of associates per subsector of activity: Viticulture (267 associates) with 27 surveys distributed; Fruticulture (143 associates) with 14 surveys distributed; Oliviculture (145 associates) with 14 surveys distributed. Although the sample size was small in absolute terms, it was representative of the target population. The survey warrants the anonymous of the respondents, all the rights regarding general data protection regulation (GDPR) rules were accomplished, and all participants allowed the use of the information and data collected.

Data were coded and entered a database and were reviewed by the research group, before been submitted to descriptive statistical analysis through SPSS software.

3. Results

The distribution of the subsectors analyzed was: 63.4% from Viticulture, 36.4% from Oliveculture, and 27.3% from Fruticulture. The majority of the respondents were males, with a majority of respondents over 50 years old, with primary and secondary education level, and were the owners of the business companies, that, in the majority of the cases, had more than ten years of existence. The responses from all the companies inquired were very similar consequently, independently of the characteristics of the individuals or of the companies they were from, there was no observation of different perceptions and use of the biotechnology tools since no correlation was found between demographic aspects and the answers. The reliability test of Cronbach Alpha was determined in the biotechnology scales (part 2 of the survey) used and presented a "Good" (0.710) internal consistency which gives 95% confidence in the data collected. The questions on part 3 of the survey, with business implications (marketing, innovation, and strategy) that could lead alow an analysis on how the business system of the companies was integrating the biotechnology use, as described later, did not allow a reliability test since it showed no cases (n = 0) in the majority of the questions.

Firms engaged in the AAPIM association vary significantly in size and scope and mainly have low annual revenues, independently of the activity subsector. With a revenue of just 125.000€, the majority of the business companies have a significant concern in saving production costs despite recognizing the difficulty they have in reducing labour and fix costs more. The perception of the firms was that innovation has moderate importance for their business and recognize that they have a weak positioning towards it (see Figure 1).

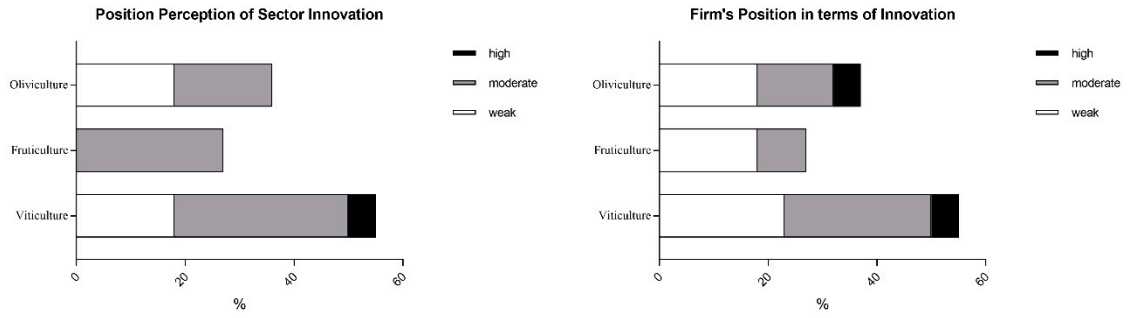

Figure 1. Innovation perception. Source: Author's calculation from the research dataset.

The environmental concern of these businesses seems something important, in particular, from a biodiversity respect perspective. However, they do not see that biotechnology is fundamental to their business strategy despite admitting that biotechnology may answer some consumer needs (see Table 1).

Table 1. Perception of consumer's biotechnology acceptance.

	Perception of Biotech Answer to Consumer Needs	Concern in Biotech Communication to Consumers	Perception of Public Biotech Acceptance	Use of Biotech Arguments to Different Products
Yes	50%	31.8	27.3%	22.70%
No	31.80%	59.1	63.6%	77.30%

Source: Author's calculation from the research dataset.

There is no communication investment of the bio characteristics of their products to the market, internal or external (they do not feel relevant to export), the reason why the majority of the firms do not recognize that patent registration as a useful tool to the competitive positioning (70% think that patent registration or other licensing is not relevant for the business). Furthermore, this is reflected in the absence of patent registration.

They devote only a small fraction of their resources to biotech-related product development or investment activities. R&D expenditures are null, as well as the involvement in Biotechnology-related activities or employees (Figure 2). Despite this, one firm has registered the participation in biotechnological research activities.

Research activities were registered for 27.3% of the firms that claimed the participation in research activities mainly in association with external R&D centres that did not belong to HEI.

In terms of product development, the viticulture sector has a higher percentage of use of biotechnology in product development than the other two sectors (viticulture—50%; oliviculture—28%; fruticulture—22%).

In most of the cases, the innovations adopted by the firms were new technological systems (Figure 3). They state no concern in launching new products (the few new products launched did not have any biotechnology implication), or new markets as they try to improve the quality of the current products produced and commercializes by them, where they recognize has already made them increase the sales volume.

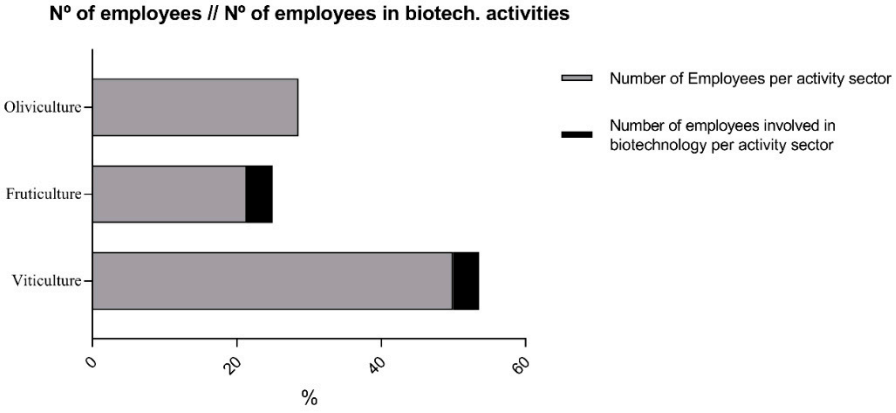

Figure 2. The number of employees vs the number of employees in biotechnology activities. Source: Author's calculation from the research dataset.

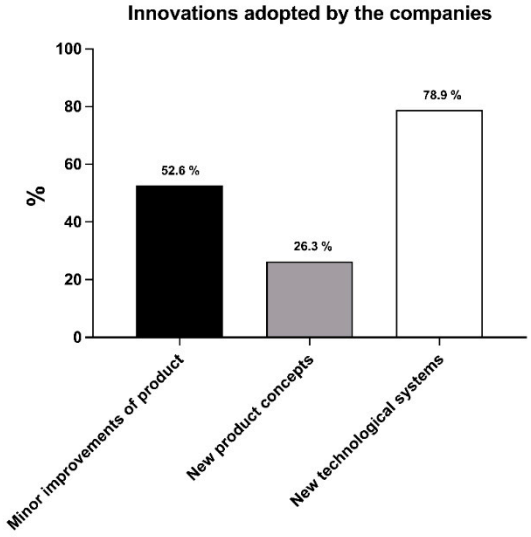

Figure 3. Innovations adopted by the companies. Source: Author's calculation from the research dataset.

Despite this, SMEs in the different subsectors states development of biotechnological activities and, in particular, the viniculture sector was the most active in the use of these techniques. DNA technologies were identified as the most frequent, followed by process/techniques of biotechnology and nanotechnology, mainly applied in the firm's processes or environmental protection (see Figure 4).

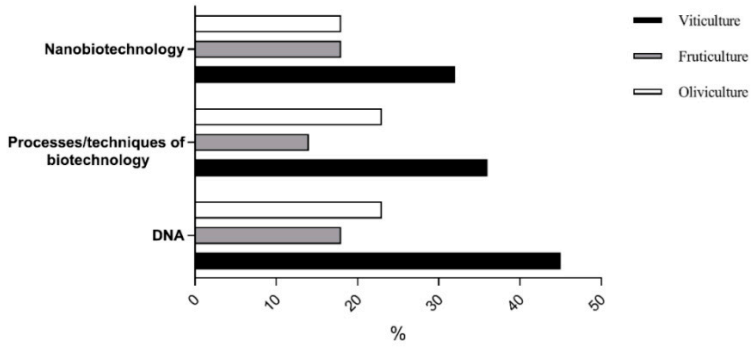

Figure 4. Biotechnology activities developed by the business per activity sector in the last five years. Source: Author's calculation from the research dataset.

These results are following the major concern stated by the firms, which was product quality improvement.

As Table 2 shows, in terms of biotechnological methods used, the majority of the firms asked to use non-GM biotechnologies.

Table 2. Types of biotechnological methods applied to the agri-food sector.

	Research	Preclinical Testing/ Limited Testing	Legislative Phase	Approved/Sold/ in Production	Not Relevant
GM-biotechnology agriculture: new genetically modified varieties of plants, animals, and micro-organisms	0	0	0	0	0
Non-GM-biotechnology agriculture-new varieties of plants, animals, and micro-organisms not genetically modified, biological control of pests	15%	15%	15%	33%	4%
Extraction of natural resources—energy, extraction of compounds, etc.	0	0	0	0	4%
Industrial processing—bioreactors to produce new products, biotechnology for transformation of inputs	0	0	0	0	0

Source: Author's calculation from the research dataset.

The firms that answered positively to the use of these techniques belong mainly to the oliviculture subsector, as Figure 5 shows.

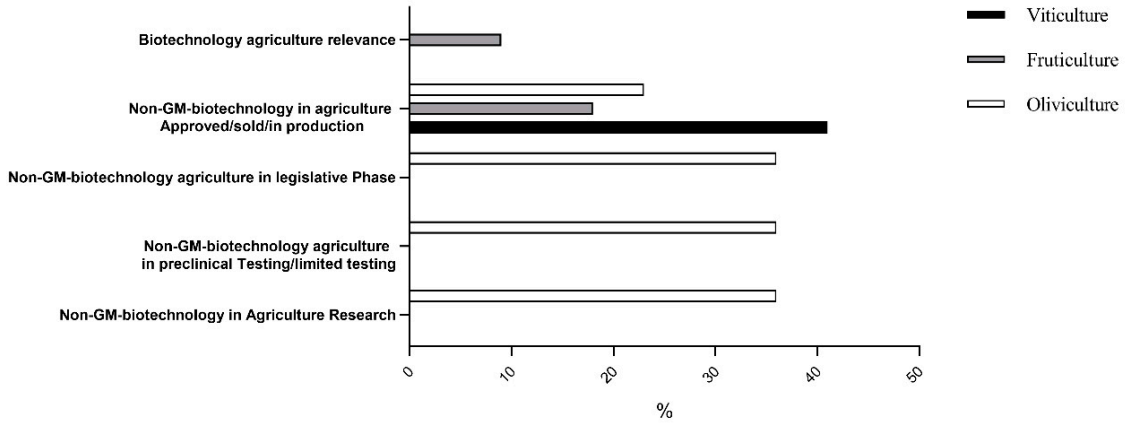

Figure 5. Sector usage of biotechnology techniques applied in the business companies studied. Source: Author's calculation from the research dataset.

In general, the businesses claimed to apply some biotechnological techniques, mainly in their production process, to improve their product quality and consequently increasing sales. They intend to answer more effectively to the needs of their national/regional market but with no concern of promoting an integrated business strategy.

The data collected in terms of business and marketing strategy highlights that, for the majority of the cases, the firms that integrate biotechnological activities within their business strategies do not deal with the market/consumers in order to enhance their efforts in offering products based in biotech processes. Despite this, they stated this as essential and even considered as their main concern, which was environmental preservation. Their business actions do not include any action of improvement in this area, not by making business associations, registering patents or developing any R&D joint activity based in pure research, or allocating employees to this type of activity. Their lack of interest in exporting is another demonstration of a lack of interest in improving their production and sales. In this sense, it is clear that the financial barrier is significant. Moreover, access to capital is one of the main barriers identified by these firms to develop their biotech and innovation processes.

Considering this and based on the polytechnic to business model implemented and registered by the Polytechnic of Guarda, an analysis was carried out concerning the first five years of implementation of the co-promotion research projects, innovative services, and specialized training (see Table 3). The co-promotion projects represented a total of €3,434,341.99 and were mainly dedicated to innovation management, marketing strategy design, and network consolidation, involving 15 companies and several partners R&D centres. Of particular relevance is the consolidation of the partnership with Inovcluster, which represents the majority of agri-food companies in the Centro Region, which develop an interface role between companies and R&D centres identifying the main challenges and contributing efficiently to the development of successful co-promotion projects. The subsectors of cheese and lactic products, wine, and olive oil were the most open to innovation and mostly related to the exportation potential as well as the dimension and technological development within the production system.

Table 3. Polytechnic to business (P2B) agri-food implementation areas of the last five years.

Lodging P2B (Ideas and Innovation Development)		
Idea/Project	**Business Partner**	**Results**
NATFARM—Product development based on thermal water	Natura Empreendimento S.A.	Co-promotion project application
Product development with natural plants	Planalto Dourado	SME 4Inova Technology and Process Award—3rd Prize
Bio packaging for cheese	Queijaria Casa Agrícola dos Arais	SME 4Inova Productivity Award—1st Prize
LDT Services—innovation services to answer business challenges and development of strategic business partnerships		
Applied Research Projects		
Project	**Funding Programme**	**Funding**
S4Agro—Sustainable Solutions for Agro-industrial Sector	Portugal Structural funds—COMPETE	€1,088,688.85
Valor Jarmelo—Jarmelista territorial recovery value for the preservation of the identity and the genetic of Jarmelo indigenous race of ruminants	Portugal Structural funds—PDR2020	€307,311.4
+Agro—Promotion and enhancement of the Mountain Olive Oil	Portugal Structural funds—COMPETE	€1,081,013.35
Promotion and enhancement of the Mountain Olive Oil	Portugal Structural funds—CENTRO2020	€586,459.71
Dermo Bio	Portugal Research funds—FCT	€147,425.83
Stai.Bin—Technological system to support the promotion and evaluation of the economic, social, and environmental impact of the short circuit SmartFarmer.pt	Portugal Research funds—FCT	€149,942.85
Partnerships and Network in Agri-food Business		
Name	**Type**	**Role**
MORE—Mountains Research Collaborative Laboratory	Non-profit Private Association https://morecolab.pt/	Shareholder founder
Network of Higher Education Institutions for the Safeguarding of the Mediterranean Diet (RIESDM)	Agreement (to consolidate research and knowledge production within the Mediterranean Diet)	Partner
Innovative Services		
Subject	**Business Client**	**Business agreement amount**
Valorisation of Natural and Dietary Products	Biosic, Sociedade de Produtos naturais, Lda	€15,000.00
International Market Study—Olive Oil Sector	Agrocluster do Ribatejo	€17,500.00
The Olive Oil Sector in Portugal—Post-production Chain Analysis	Agrocluster do Ribatejo	€20,000.00
Strategic Analysis for the Olive Oil Sector	Inovcluster—Associação do Cluster Agro-Industrial do Centro	€21,000.00
Boxes of Training (specific training courses to answer business needs)		
Course	**Area**	**Education Level**
Management and Innovation of Endogenous Products	Business and Agri-food	Professional Higher Technical Courses (EQF and ISCED level 5 course)
Policasulos (Incubator and Accelerator Centre)		
Entrepreneur Project	**Entrepreneur Team**	**Business Creation**
FruMo (Chestnut Valuation)	Alfeu Magalhães	AgroTamanhos (Agricultural cooperative)
Royal Roe (Marketing of Trout Roe)	Débora Soares; Samuel José	Project
Pearl Culture	Cláudio Manuel Alves Ferreira	Project

Source: Author's calculation from research dataset.

4. Discussion: R&D Collaboration, and Open Innovation in R&D

Most of the firms in the sample are strategic followers, with null R&D expenditures. Despite this, they have a moderate perspective about the role of biotechnology and innovation for their business core, assuming its weak commitment in this area. Also, it was registered that they do not devote special attention to have qualified staff for product development or R&D activities. The new products introduced in the market by these firms do not result from R&D activity outputs. These findings confirm that a lack of technically qualified competences constitutes one of the most determinant constraints to innovation by small firms, and as was stated and reviewed in other works [34,53–55].

Another critical aspect resulting from data analysis is the low R&D activity of these small firms involving R&D partnerships. On the other hand, it was mentioned that this activity, when it exists, depends on external R&D centres. This aspect is of utmost importance, once European research policy highlights the effectiveness of the proximity approach of research centres from local universities to the innovation of local and small firms to improve the knowledge and technology transfer [39,56]. If this worked, this partnership would also change the non-patent registration relevance for the business scenario, since for the R&D centres its essential and a way to show their work. This situation, as Grillitsch et al. stated, is typical of non-patent-intensive sectors; therefore, it should not be used as a research/innovation indicator [19]. We also observed that, in this situation, it is beneficial to a university-enterprise relationship to improve and develop an important role in technological business success [57]. In fact, and as was registered for other industries, which have experienced a strong positive effect with the application of open innovation concept and practice, the development of technology and joint patent applications within university—enterprise partnerships increases the market value of the patent [58].

Future research could reveal how this partnership would improve business development and success analysing the enterprise R&D organizational ambidexterity and how it promotes this type of small agribusiness evolution, considering its life cycle and development model, and therefore be able to help these companies to integrate the biotechnology use and concern in their business strategies [59]. Other innovation strategies for this type of small agri-food business could be supported on the development of new business models since they lead to market growth and it is required technology development to implement it maturely [60]. In this way, they could foresee more easily the need to develop and integrate new technology and they would establish new markets within an open innovation strategy. The "new" concept of bioeconomy based on the sustainable exploitation of biological resources, has emerged as a critical strategy to meet resources use efficiency and innovative processes and products. In this sense, consumers and producers share environmental concerns, as also registered in this study. In fact, in this study, farmers assume the quality improvement of products as their focus and non-GM biotechnology tools were recognized as useful for eco-innovative product development following the actual green trend widely discussed and reviewed in previous works and reports [61,62].

Resources constraints have long been recognized as one of the factors that impact on the business performance and growth of SMEs. Small-sized SMEs limits innovation and limit access to capital investment on innovation. The findings of this study about the evidence supporting the lack of agri-food SMEs capacity and competences to access to capital to improve their production and sales based on biotechnological innovation incorporation are entirely following the significant concerns of national and European Union Policy that highlights regional networks as the bottleneck for achieving knowledge and technology dissemination as reviewed by Muscio and Ciffolilli [63].

Furthermore, researchers can be encouraged to realized open innovation in the agri-food industry by the design of new and better balanced internally and externally R&D incentive systems to encourage the researcher to take on the challenge [64]. Another point, which can contribute to the development of the agri-food industry, is the open innovation produced from other industries because most innovation is based on a recombination of existing knowledge, concepts, and technology [65]. In this sense, we also confirm that the supply chain collaboration is a determinant for the agri-food industry.

Regional inter-organizational collaborations for creation and diffusion processes have been considered more successful when reflected not only the geographical proximity but also institutional, technological, social, and organizational proximity. For this, the existing local and regional network between agri-food firms, farmers organizations, and research centres from higher education institutions was considered crucial to the future developments of this sector [66–68]. As stated by Enkel and et al. (2009) [69] a coupled process of co-creation innovation would have significant benefits for this industry, since the cooperation with external R&D entities is fundamental to overcome competitive disadvantages when this innovation collaboration is not implemented and taking into account the constraints find in external knowledge transfer.

5. Conclusions

This study, despite the small size of the sample, characterizes the SMEs of the agri-food sector from Centro Region of Portugal regarding innovation consistently and constitutes the first analysis ever of the regional innovation system in agri-biotechnology. Is clear that the SMEs in this study demonstrated a higher level of engagement with monitoring their marketplace, and other marketing activities, as some other, studies already highlighted [70]. Results highlight that investment acts as a constraint in the path of introducing innovation in this sector and in engaging these SMEs in a more competitive strategy supported by it. Therefore, policymakers should consider strategies that can assist agri-food sector SMEs in accessing and managing resources for innovation through regional networks involving producers, organizations, and research centres. Also, regional HEI and their research centres, assisted by the policymakers, may engage in education and research activities that support actions to help these SMEs.

Lastly, there is potential for considerably more research into innovation in SMEs in general, and in the agri-food sector, in particular, to be able to draw business strategies to introduce innovation in the SMEs management and production.

It is important to develop an action plan that can integrate the consumers and suppliers of innovation (R&D regional network) to reinforce the proximity and the development of applied projects with a real and positive impact on the economic sustainability of regional SMEs. This fact is of the utmost relevance within the agri-food sector that quickly can internalize innovation in the economic and marketing strategies considering the development of high-value products based on a sustainable biotechnological approach.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A Biotechnology Use Survey

With this survey, we intend to understand how companies in the agri-food sector use biotechnology in their activity and how they can integrate biotechnology into their business strategies as a competitive factor.

Part 1—Business and Employment

1.1 How many employees your company has? _____

1.2 How many of your employees are involved in biotechnology activities? _____

1.3 How many of its employees involved in biotechnology activities develop:

- Research activities
- Other biotechnology activities (ex.: Production)

1.4 How much time have their employees spent developing:

- Biotechnology research activities
- Other biotechnology activities (ex.: Production)

1.5 What is the billing volume of the company?

☐ <125,000 €
☐ 125,001 to 250,000
☐ 2,500,001 to 5,000,000
☐ 5,000,001 to 10,000,000
☐ >10,000,001

1.6 What is the amount in research spent by the company per year? _____

Part 2—Biotechnology

2.1 Point out the biotechnology activities used by your company in the last 5 years:

☐ ADN—genomics, pharmacogenomics, genetic engineering, DNA sequencing/synthesis/amplification, gene expression profiles, etc. (Ex: genetically modified organisms, transgenic organisms, genetic improvement of species, selection of varieties)
☐ Cell cultures and tissue engineering—cell and tissue cultures, tissue engineering, cell fusion, vaccines/immunostimulants, embryo manipulation, micropropagation.
☐ Biotechnology processes/techniques—fermentation through bioreactors, bioprocesses, bioremediation, phytoremediation (Ex: bioprocesses and bioreactors, biofertilizers, biological struggle, biopesticides, bioherbicides...)
☐ Bioinformatics—creation of genome databases, protein sequences, modelling of complex biological processes, including biological systems.
☐ Nanobiotechnology—application of nano/microfabrication tools and processes in biosystems study (Ex: veterinary products, vaccines, biotechnical fight (semi-chemicals, insect growth regulators, self-acid fight)
☐ Another: (specify) _____

2.1.1 If you answered yes, say what kind of use it makes of biotechnology:

- Do you research on this biotechnology use? □
- Do you use this biotechnology for product or process developments? □
- Do you use this biotechnology in production process (including for environmental purposes)? □

2.2 Does your company currently develops processes that require the use of biotechnology? Yes □ No □

2.3 Does your company applies the following biotechnology applications:

	Research	Pre-Clinical Testing/ Limited Testing	LEGISLATIVE Phase	Approved/Marketed/ in Production	Not Relevant
GM—biotechnological agriculture: new genetically modified varieties of plants, animals, and micro-organisms					
Non-GM—biotechnological agriculture—new varieties of plants, animals and non-genetically modified micro-organisms, biological pest control					
Extraction of natural resources—energy production, extraction of compounds, etc.					
Industrial processing—bio reactors to produce new products, biotechnologies for input transformation					

2.4 When did your company put biotech products on the market? _____
2.5 Your company currently develops products that require the use of biotechnology? Yes □ No □

Part 3—Strategy and Marketing

3.1 What is your idea about the level of innovation in the sector? Weak □ Moderate □ High □
3.2 How do you position your company in terms of innovation? Weak □ Moderate □ High □
3.3 What kind of innovation has your company already adopted?

- Minor product improvements □
- New product concepts □
- New technology systems □

3.4 Does your company has developed research activities? Yes □ No □
3.4.1 If you answered yes, please indicate which research activities you have developed:

- Developed research activities internally? □
- Developed research activities in association with other companies? □
- Developed research activities with external research centres? □

3.4.1.1 Please indicate which research centres have carried out research:

- ○ Research centres of higher education institutions □
- ○ Other research centres □

3.5 In the last 5 years, how many products has your company has launched on the market? _____
3.6 How do you classify your company's innovation objectives? Weak □ Moderate □ High □
3.7 What kind of innovation objectives have you achieved?

- Replace end-of-cycle products □
- Improve product quality □
- Extend the product range □
- Access to new markets □
- Increased sales volume □
- Comply with legislation and standards □
- Lower labour costs □
- Decrease material consumption □
- Decrease energy consumption □
- Reduce environmental damage □
- Preserving biodiversity □

3.8 Do you consider biotechnology to be a central issue for your company's activity and/or strategy? Yes □ No □
3.9 Does your company knows the mechanisms of industrial property? Yes □ No □
3.10 How you defend ownership in the face of competition?

- Keep secret □
- Knowledge is tacit □
- Development and market times are relatively short □
- Protects using patents □

3.11 Does your company holds patents in the field of biotechnology? Yes □ No □
3.11.1 If so, how many patents your company holds? _____
3.12 What are the barriers you consider most relevant for the implementation of biotechnology techniques?

- Difficulty in establishing partnerships with R&D centres □
- Access to capital □
- Access to specialized human resources □
- Access to international markets □
- Difficulty in distribution and access to distribution channels □
- Acceptance/perception of the public □
- Legal requirements □
- Patent rights and other licensing costs □

3.13 Do you consider that the biotechnological issue meets the needs of consumers? Yes □ No □
3.14 Do you use biotechnological arguments to differentiate your products? Yes □ No □
3.15 Are you concerned with informing its consumers about the biotechnological characteristics of its products? Yes □ No □
3.16 Do you consider that introducing biotechnology into your company's strategy is an opportunity? Yes □ No □ Or a risk? Yes □ No □
3.17 Is biotechnology part of your company's mission and strategy? Yes □ No □
3.17.1 If so, how does it develop its strategy considering the biotechnology factor?
3.17.1.1 Action in the internal market:

- ☐ Supply of genetic materials from your own country.
- ☐ Biodiversity conservation agreements with national governments.
- ☐ Direct involvement in biodiversity conservation practices in the internal market.
- ☐ Contributions to conservation efforts.
- ☐ Affiliation in a conservation action group.
- ☐ training and development of conservation professionals.

3.17.1.2 Action in developed countries:

- ☐ Supply of raw materials from developing countries.
- ☐ Direct involvement in biodiversity conservation initiatives in developing countries.
- ☐ Biotechnology development agreements in developing countries.
- ☐ Joint ventures with companies in developing countries for conservation reasons.
- ☐ Establishment of research facilities in developing countries for the conservation of materials.
- ☐ Contributions to conservation efforts in developing countries.

3.17.1.3—Biodiversity conservation agreements:

- ☐ Organic extraction agreements (payment of user tax to developing countries in exchange for access to protected natural habitats).
- ☐ Biological prospecting agreements (user fee paid to developed countries, along with royalties arising from the development of consequential products).
- ☐ Sampling agreements (fee paid to developed countries in exchange for the collection of samples of plants and animals).

Part 4—Respondents
4.1 Sex: F □ M □
4.2 Age
- Less than 30 years
- From 30 to 39 years
- From 40 to 49 years
- From 50 to 59 years
- Over 59 years old

4.3 What position do you hold in the Company? _____

4.4 Academic level:
- Basic Education
- Preparatory Teaching
- Secondary School
- Degree
- Master
- PhD

4.5 Seniority in the Company:
- <5 years
- 5 to 9 years
- 10 to 19 years
- 20 to 29 years old
- More than 30 years

4.6 Economic Activity Classification (EAC): _____

4.7 Year of Company Constitution_____

☐ I allow my data to be used regarding the research purpose of the study "Biotechnology Use Survey" develop by the research team of Polytechnic Institute of Guarda and AAPIM technicians, complying with GDPR rules.

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Trouble in Paradise? Barriers to Open Innovation in Regional Clusters in the Era of the 4th Industrial Revolution

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Abstract: The purpose of this paper is to provide an insight into the barriers faced by clusters as open innovation intermediaries. Literature review and an empirical study were performed, involving a nation-wide survey, case studies, and in-depth interviews with cluster actors involved in open innovation activities. This article conceptually links open innovation and clusters in the context of the fourth industrial revolution, empirically identifies barriers hindering open innovation in clusters, and indicates factors that might affect the open innovation processes in networked ecosystems. The findings confirm that the perception of barriers hindering open innovation in clusters differs between clusters already implementing open innovation and those which are still not active in this area. The findings contribute to a comprehensive understanding of the potential roles of clusters as open innovation intermediaries in the context of transitioning economies. With clusters playing a role in open innovation intermediary, public support at cluster level could increase openness to cooperation not only for member companies, but all participants in the regional innovation ecosystem.

Keywords: open innovation; regional clusters; open innovation intermediary; innovation ecosystem; 4th industrial revolution; innovation policy

1. Introduction

The fourth industrial revolution is a concept of organizational and technological changes along with value chains integration and new business models development that are enabled by innovative technologies, connectivity, and IT integration [1]. The advancement of integrated processes necessitates the development of proficiencies that will be to a greater extend relational, cognitive, and analytical, and will require close cooperation with the external partners of a company. To maintain and leverage capability to collaborate, however, it is necessary to manage open innovation models, involving different actors in the collaboration process, with different motivations and purposes [2]. The concept of open innovation (OI) holds that innovation capabilities are spread among many actors of an innovation ecosystem [2–4].

Regional clusters seem to provide a conducive environment to OI because significant and beneficial improvements to OI processes are induced by the geographical proximity [5–7]. Specifically, Simard and West [8] recognized regional clusters as a perfect framework to analyze OI because of the existence of two pivotal factors: networking involving many actors and the flows of knowledge. There is a suggestion [9] that the OI model leads to benefits that can be further augmented in regional clusters. The majority of existing literature, however, has concentrated on a micro-level view [10,11] or macro-economic issues [12,13]. We hope that this paper will contribute to the narrowing of this gap in research by taking a meso-level perspective in its examination of OI in the context of the fourth industrial revolution.

Clusters, especially in transition economies, are predominantly composed of small and medium enterprises [14]. Research shows that, while for large companies open innovation is a strategic choice to access complementary assets and capabilities better mastered by their partners, for SMEs, open innovation is a necessity as it helps compensate for the resources and assets that they lack [15–17]. There is a considerable variety in the effectiveness of different clusters, prompting a need to examine it further and to understand barriers to open innovation vis-a-vis regional clusters.

The above considerations were the basis for formulating research questions for an exploratory study:

Q1: What are the main barriers hindering open innovation in regional clusters?

As the attitude towards this relatively new phenomenon might be conducive to change alongside the experience of clusters and cluster members in introducing the open innovation model, the second research question of the study is

Q2: Do perceived barriers differ between clusters, active and non-active, in the area of open innovation?

This study was performed in the context of a transition economy. Transition economy is an economy which is changing from a centrally planned to a market economy [18]. To date, most of the research on open innovation can be found in advanced market economies. The importance of a transition economy context is justified as the institutional environment shapes the structure of political, social, and economic incentives, and thereby, limits the scope of the strategic choices available to individuals and organizations [19] and influences the use of open innovation strategies by companies [20]. It is believed [21] that research opportunities are available within this area to uncover processes which can surmount the low level of trust in order to facilitate cooperation in an innovation ecosystem.

The originality of this paper stems from this, it being the first focusing on practical experiences of clusters as intermediaries of open innovation in the context of transition economy. The paper might be seen as a contribution to the emerging literature on the spatial, cultural, and organizational dimensions of open innovation. Moreover, it expands previous research on cluster channels' likely impact on open innovation in SMEs.

This paper is structured as follows: First, the basic premises and the connections of open innovation and cluster concepts with regards to the fourth industrial revolution are discussed. Thereafter, the mixed-method research design is presented. In the next sections, the results of the study are presented and the barriers to the clusters' potential role as open innovation intermediaries are analyzed and discussed. Finally, conclusions, contributions, and limitations are presented.

2. Literature Review and Research Framework

Open innovation connects the micro-, meso-, and macro-levels of innovation analysis [22]. OI continuously enhances innovation competency by allowing business models to be dynamically created, altered, dissolved, and recreated. This occurs through the exchange of knowledge and co-development of products in loosely coupled networks of companies and other relevant actors [23].

This study builds on the conclusion that collaborating with external partners offers the benefit of risk diversification wherein uncertainties are shared. Adopting an OI model eliminates a company's dependence on its own R&D for innovation [3,24]. As a result, interorganizational networking must be used extensively to capture, incorporate, and expand on both knowledge and ideas [2]. Networking is essential when considering the OI model's two explicitly different processes: inside-out and outside-in. The former refers to the offering of knowledge, ideas, and innovation which have not been absorbed by the company. The latter reflects the augmentation of the company's own knowledge base by acquiring innovation from external sources or partnerships [25]. Therefore, both inside-out and outside-in processes benefit from networking with and the cultivation of a diverse group of external actors.

Many OI studies stumble upon the fact that there is no specific definition of open innovation activities but rather a wide range of cooperative undertakings—with different levels of maturity and openness. Open innovation is about the implementation of activities relevant to the acquisition and

usage of external knowledge ranging from user-centered innovation, commissioning R&D services, and even going as far as the free revelation of knowledge [21,26]. None of these types of cooperation practices are clearly identifiable and partly overlap. In addition, the tools used to implement open innovations are very diverse in terms of their assumptions and the goal to be achieved as a result of their application.

Nonetheless, the research stream has identified multiple benefits of open innovation relating to an increase in individual company's innovation performance. It is acknowledged as an approach to the acceleration of internal processes and innovative efforts [27]. There is an expectation that OI will provide a company with access to knowledge and resources, which would otherwise be unavailable. There is a further expectation that it will enable firms to reach both strategic and financial potential from actively commercializing knowledge [21,22,25]. Increasing cooperation propensity, in that regard, is also seen as a prerequisite for sustainable Regional Innovation Systems [28].

However, multiple barriers to OI have been recognized in several studies [29–32]. Many companies, SMEs in particular, lack not only in resources but also in the capacity to take advantage of OI [33]. The same applies to the development of organizational learning routines that require resources difficult to provide, for instance, dedicated managers to coordinate multiple networks [34]. Apart from the resource constraints, there are a number of cultural and psychological barriers to OI such as the Not-Invented-Here (NIH) and Not-Used-Here (NUH) syndromes that impede open innovation practices. This is due to the fact that the implementation of open innovation model [22,35]

- Is based on the managers conducting a primary evaluation of external knowledge and competences;
- Is established through the company's employees' willingness to cooperate;
- Is evaluated against the ability of the company to take maximum advantage of intentional outflows and inflows of information.

Another main barrier that often emerges is the fear of competitors gaining significant knowledge when a company is revealing internal matter [36]. This gives rise to a paradox of openness—the creation of innovations often requires openness, but the commercialization of innovations requires some form of protection [37]. For this reason, important decisions as to the degree of openness are contingent on the range of appropriation strategies to which the company has access [38].

An intermediated network approach has repeatedly been proposed as a solution both to support collaboration for innovation and to overcome barriers, especially those which prevail in SMEs [39,40]. According to De Silva et al. [41] and Howells [42], intermediaries provide a supporting function for the cooperation of parties throughout the process of innovation. Innovation intermediaries are sometimes necessary because open innovation by its very nature is deliberate. An appropriate framework is called for as a prerequisite to facilitating open innovation practices for integrating and commercializing of external knowledge. Clusters seem to fulfill that role and are believed to be successful innovation intermediaries; however, most of the research in that area was performed in the advanced economies [31].

Innovation clusters are agglomerations of cooperating companies, organizations, and governments, which are geographically localized. There is an interactive pairwise collaboration between the various types of these networked actors. They enjoy a highly developed pattern of cooperation associated with the triple, and subsequently, the quadruple helix model, wherein society also plays a role [43–45]. A study by Claver-Cortes et al. [46] offers summarized evidence of the impact of clusters and takes into consideration factors such as capital productivity, labor productivity, and innovation intensity. Clusters contribute to the furtherance of the fourth industrial revolution by increasing the competitiveness and attractiveness of a region [47]. Due to policies of regional diversification and smart specialization, there is a suggestion that the 4th industrial revolution is an era "beyond clusters". However, according to Suwala and Micek [48], it is certainly not a "post cluster" era. Clusters which are successful are shown to be built on a "practice of clustering", i.e., a set of future-oriented activities carried out jointly by regional actors and coordinated in order to enhance the local texture [14,49,50].

This study links clusters as industry networks with a concept of the fourth industrial revolution, implying technological and organizational challenges which afford opportunities for [51–53]

- Developing a more responsive management embracing a culture of openness and collaboration;
- Cultivating new skill sets among change agents;
- Creating and reinforcing networks of collaboration involving various partners.

Clusters seem to offer a conducive environment facilitating those challenges and implications. They provide a favorable knowledge environment, simplify and increase the efficiency of the business processes, and organize the policy-making in this area [14]. The fourth industrial revolution not only utilizes platforms, but also calls for a shift from value chains towards highly flexible networks of interconnected actors. Thanks to this, clusters appear to be fittingly positioned to act as central elements in such configurations.

Moreover, there are several global grand challenges that affect economies in all stages of development and call for open collaboration [21,54]. Unfortunately, although there has been increased adoption of open model of innovation in developed countries [55], firms from transition economies, such as Poland, distinctly fall short. In Polish conditions, companies are very reluctant to cooperate with scientific and research institutions [56]. However, the significant changes currently resulting from the fourth industrial revolution have presented new opportunities for leapfrogging to companies in transition economies.

3. Materials and Methods

This study is a part of a nation-wide, multi-stage research project on open innovation in clusters. It is of an exploratory nature because there is, to date, a lack of systemic investigation in the research into open innovation and clusters. The data used for this paper stem from two main data sources:

- A quantitative survey among coordinators of 31 clusters located in Poland;
- A qualitative analysis of two case studies of clusters, based on semi-structured personal interviews with different groups of stakeholders (9 actors from the two respective clusters).

3.1. A Survey

The subject of the survey was a cluster initiative, which is a cooperation platform and a tangible manifestation of cooperation between companies. The person filling in the questionnaire was the cluster coordinator, i.e., the potential or actual organizer of open innovation in the cluster. The selection of the sample was deliberate and covered the entire population of active cluster initiatives in Poland, which was estimated at 81 initiatives at the time of the study. Active clusters were those meeting the basic requirements of the cluster management standards developed by the Polish Agency for Enterprise Development. The criteria included having entities from business, science, and administration as members; conducting activities and events for the cluster participants; coordinating at least one joint project with cluster members; and having a website or other platform for remote communication with participants. It was decided to carry out the original survey among cluster coordinators, because as such they are involved in facilitating the innovative cooperation of member companies. Additionally, representing the entire community of participants, they often collect data on various activities performed by members [14].

An email with a dedicated link to the online survey was sent to all coordinators of the identified active clusters in Poland. In addition, information about the study was sent to the appropriate units of regional and local administration to be forwarded to clusters operating in a given region. A total of 31 cluster initiative coordinators completed the questionnaire, representing a return rate of 38.2%. It was concluded that the returned questionnaires are representative for the target population. Clusters represented 16 industries, with the most common industries represented being ICT industry; energy and renewable energy sources; biotechnology; food industry. The examined initiatives have been

functioning on average for over 7 years (minimum 2 and maximum 14). The studied clusters had an average of 69 members (median 50). The smallest of the clusters had 12 members, and the largest over 300. The share of SMEs as cluster members was above 75% in all of the clusters taking part in the survey.

Open innovation may involve the use of various methods and tools. Despite several years of research in this field, the challenge for researchers is the diversity of practices of implementing an OI model especially in the network context. There is no official classification of open innovation activities, and all the more none on the cluster level. We operationalized open innovation activity at cluster level as a second-order construct, measured by 9 items. The open innovation activities were adopted to the cluster context from activities most commonly presented in the literature on open innovation regarding individual companies [57–60]. In the survey, the list of open innovation activities at cluster level consisted of following actions—cluster is actively engaging in and directly supporting:

- Acquiring expert knowledge (outside of member companies), e.g., designing a new product in the partnership of several companies, providing research and development facilities for members, partner investment projects;
- Technology transfer and license trading, e.g., support in purchasing a license to use a given technology, assistance in acquiring partners, consultancy in the field of intellectual property rights protection;
- Platforms and complex systems, e.g., creating a common product development platform for several cluster members, testing products in a real environment, demonstration projects;
- User-driven innovation, e.g., support cluster members in involving users in designing, testing or implementing new products;
- Knowledge crowdsourcing, e.g., organizing an open competition to solve a given problem or using a virtual community to implement new products;
- Open data, e.g., support in sharing or obtaining open data for business purposes;
- Social innovations directed to the public sector or communities, e.g., supporting the creation of products aimed at improving the quality of life of individual groups of people or entire communities;
- Design thinking, e.g., support in design activities using rapid prototyping;
- Mass customization, e.g., supporting member companies in offering customers individually tailored products on the mass market, but at relatively low prices.

Respondents were asked to indicate from a list the types of open innovation activities that are carried out at the cluster level, e.g., actively facilitated by the cluster coordinator. They were also asked to indicate the scale of these activities (small or large scale). In this study, it was assumed that open innovation activity is being undertaken in the examined cluster when at least one of the nine types of activities listed in the questionnaire was undertaken on a significant scale. The considerable scale of the activity indicates the involvement of various types of resources to implement an open innovation activity.

Five-point Likert-scale ranging from 1 (not important) to 5 (very important) was used to assess the barriers to open innovation at the cluster level as perceived by the cluster coordinators. Descriptive statistics were used to analyze the results. In a pilot study, a group of cluster coordinators completed the survey to check for understandability. The questions regarding barriers to open innovation at cluster level were asked both in the clusters performing open innovation activity as well as in those not performing such activities and were then compared. The barriers were adopted to the cluster context from the barriers faced by individual companies, especially SMEs [29–32]. Additionally, conclusions from the pilot study and an expert panel—earlier phases of the research project that this study is a part of—were taken into account [36]. In the survey, the list of barriers consisted of

- Significant costs of open innovation cooperation;

- Costs in relation to expected effects;
- Concerns of member companies about intellectual property rights (IPR);
- Lack of knowledge about methods and tools of open innovation;
- Companies' fear of losing control over the innovation process;
- Unwillingness to delegate essential employees;
- Difficulties in managing joint open projects;
- Low potential to absorb innovations in companies;
- Companies feeling no need for open innovation.

3.2. Case Study Analysis

The case study analysis was applied to two clusters that operate in high-tech industries and carry out extensive open innovation activities. The selection of case studies was based on the classification of a phenomenon-driven approach, which is usually applied when the investigated phenomenon is dynamic and complex [61]. Cases were chosen from a pool of clusters which ranked the highest in the preceding survey in terms of the number and scale of different open innovation activities. The purposeful sampling was applied on the basis of possibility of clearly illustrating the studied issue. In addition, the cases were chosen to come from different industries and represent a different strategic approach to OI activities, which have given an additional perspective of comparing them with each other. In addition to research objectives, the selection of these specific cases was also dictated by the possibility of their use in business practice as a benchmark and a source of a good practice. One of the cases was an IT cluster with 120 members operating for 9 years. The second one was a biotech cluster with 40 members operating for 7 years. Both clusters have an over 75% share of SME among members. The clusters are located in different regions and perform many open innovation activities for their members. Both clusters were established through a bottom-up approach of companies and other ecosystem actors with a goal of enhancing effectiveness of these companies' business performance through coopetition.

In order to gain data for the case study, 9 semi-structured personal interviews (CAPI method) with actors from those two clusters were performed. The actors represented companies (6 actors), R&D or higher education institutions (2 actors), and a regional administration responsible for regional cluster and innovation policy (1 actor). All actors were actively involved in open innovation activity of selected clusters. The interviews were conducted in a semi-structured way, aimed to better understand the observed barriers. The interviews took place in the first quarter of 2018 and lasted between 45 and 60 min. All interviews were recorded, and transcriptions were subsequently made. Although an open approach was taken to permit different stakeholders to describe barriers to open innovation in their clusters, some supplementary questions were added in order to align the interviews and to allow for comparison of the data.

4. Results

4.1. The Survey

The findings of the survey study show that 17 out of 31 examined clusters (55%) engaged actively in open innovation activity, i.e., undertook at least one type of open innovation actions (on a significant scale) from the nine actions listed in the survey. Over 45% of clusters did not undertake in any of the types of open innovation activities. The ones that did, did on a very small scale. In accordance with the base line of this study, those clusters were then treated as not undertaking open innovation activity. The analysis and interpretation of research results was made, taking into account the division of clusters into the above two groups. No significant correlation was found between the type of barriers to OI and other grouping factors like age, size, or industry of the cluster.

The most common type of open innovation support for their members in the studied clusters were activities related to platforms and complex systems—14 surveyed clusters (45%) have undertaken such

activities on a large scale. Obtaining expert knowledge from outside member companies was the second most popular type of open innovation activity. This type of activity was undertaken on a significant scale by the nine studied clusters (29%). Each of the groups of activities of the following types—social innovations, crowdsourcing, technology transfer, and license trading—were implemented by six clusters, respectively. Another type of OI activity—user-driven innovation—was implemented in five initiatives (16%). Fewer initiatives carried out design thinking (4% and 13%). The least popular activities are those related to open access to data and mass customization. Only a few initiatives (2 and 1, respectively) have implemented them on a significant scale (source hidden as it refers to a previous paper published by the same authors). All of the clusters participating in the study were planning to start or enhance support for open innovation for their members in the next 12 months.

In the study, cluster coordinators were asked to indicate the importance of the listed barriers to support open innovation among members on a five-point Likert scale. The responders assigned the most importance to the barriers related to difficulties in managing joint projects, concerns of participating companies about intellectual property rights. The third most important barrier was the assessment of costs in relation to expected effects. The least importance was assigned to a statement that the member companies did not feel the need for cooperation. The (weighted) average importance is presented in Table 1.

Table 1. Assessment of the barriers of open innovation in clusters (1–5 Likert scale).

Barriers of Open Innovation in Clusters [1] (1 = Not Important, 5 = Very Important)	**Average for All Clusters (N = 31)**	**Average for Clusters Facilitating Open Innovation (N = 17)**	**Average for Clusters not Facilitating Open Innovation (N = 14)**
difficulties in managing joint open projects	**4.2**	**4.1**	**4.3**
concerns of companies about intellectual property rights (IPR)	**4.1**	**4.1**	4.1
costs in relation to expected effects	**4.1**	**4.1**	4.1
lack of knowledge about methods and tools of open innovation (OI)	4.0	3.7	**4.4**
fear of losing control over the innovation process	3.9	3.6	4.1
low potential to absorb innovations in companies	3.9	3.6	4.1
significant costs of OI cooperation	3.8	3.5	**4.2**
unwillingness to delegate essential employees	3.5	3.1	3.9
companies feeling no need for OI cooperation	3.2	3.1	3.3

[1] The three most important barriers for a given group are marked bold and underlined.

Among the clusters undertaking open innovation, similarly to the results for all the clusters, the coordinators assigned the most importance to barriers related to difficult management of a joint project and companies' concerns regarding intellectual property rights. Barriers related to lack of knowledge of open innovation tools in the initiative, low absorption potential, or significant costs of cooperation were relatively less important. On the other hand, cluster coordinators that did not actively support open innovation attributed the most importance to barriers related to lack of knowledge about tools and methods, difficult management of a joint project, but also potentially high costs of cooperation (which in the case of initiatives actively open innovation were not that significant).

4.2. Case Studies

Analysis of the two case studies allowed to confirm the main barriers hindering successful support of open innovation in clusters but also indicated solutions to at least some of them. A barrier that most commonly appeared in the interviews was the issue of initial uncertainty regarding intellectual property rights. Before the commencement of cooperation, some companies from the OI active clusters also had considerable concerns related to securing know-how in joint projects. However, among enterprises that previously participated in these types of projects within the cluster, these issues were no longer a cause for concern. As one of the cluster members put it: "It's the first one you are anxious about. But if you have been involved in at least one project like this, you already have a grasp and you are set up to deal with the next one, without unnecessary doubts".

In each open innovation project implemented by the studied OI active clusters, the issue of intellectual property rights was solved individually. Model solutions proposed by the cluster coordinator (e.g., model contract, availability of an IPR specializing lawyer) and areas of cooperation discussed in detail reduced fear to a minimum and was no longer seen as a barrier. The most frequently defined areas of confidentiality were the areas of open access to the results of jointly generated research, in particular in projects co-financed from Horizon 2020 funds. Consortium coordinators took special care of defining the scope of using the project results and the contracts were agreed in a fine detail. A cluster coordinator from one of the initiatives underlined: "We have a specialized legal counsel in place to make sure that all the parties involved in the open innovation project are able and willing to share some precisely described internal knowledge and at the same time are satisfied with the results of the cooperation and accordingly protected."

Another barrier to open innovation at cluster level indicated by interviewees from both examined initiatives is distrust among entrepreneurs as to whether such cooperation will bring measurable benefits in relation to potential costs and risk incurred. It was rather an issue of trust in potential partners for such a cooperation and risk of costs in case of an unsuccessful/failed cooperation than the actual costs of undertaking open innovation activities. There is an initial high-level of distrust, even between member companies. Respondents emphasized that there is still lingering belief among entrepreneurs that if they want to sustain a competitive advantage, they should create solutions internally within the company, which without external support is very difficult, especially for SMEs. This seems to be a barrier of a much bigger significance in the transition economies than in the developed market economies with effective institutional and organizational structure. On the other hand, respondents from companies that have engaged in open innovative cooperation, even after initial reluctance, are afterwards very eager to undertake subsequent joint projects, emphasizing that any financial and time expenditures connected to open innovation have been recovered many times, both in the form of financial as well as increased organizational and technological potential of the company. A representative of a member company was very straightforward: "If we knew earlier, how much we would gain from open innovation projects, we would engage in them much sooner".

The barrier of difficulties in managing join projects came up in all of the interviews. According to interviewees, joint activities in the area of open innovation require the parties involved to demonstrate a high level of organizational and communication capabilities as well as a certain maturity. The cooperation imposes the duty of careful administration, compliance with certain rigors of cooperation, and empathy towards the needs of partners and the entire consortium. Many companies, according to respondents, still have trouble with this approach and need cluster support in this regard. Within both of the examined OI active clusters, coordinators encouraged members to enter open innovation projects, support managing of joint projects but require for the companies to be very proactive and share responsibility for the entire process.

There is a large group of companies, also in the OI active clusters, which for various reasons do not currently have the technological and/or organizational potential to cooperate with external partners. Companies, for example, focus on using the current business model and do not feel the need for development. There is also a group of dynamically developing companies trying to manage

technological processes in the same way they were managed when the company was small. According to interviewees, companies in transition economies, like Poland, seem to underestimate the role of technological and organizational support and consulting. The studied clusters are trying to show the importance and effects of this type of support, in particular for SME companies that are not always fully aware of the benefits or are not able to obtain such services on the market.

5. Discussion

Regarding the first research question (Q1), the results of this study are in line with previous research findings regarding barriers to open innovation in SMEs [29–32] and emphasize the following barriers preventing clusters from adopting OI on a larger scale among member companies:

- Concerns of member companies about intellectual property rights (IPR);
- Difficulties in joint project management;
- Limited knowledge about open innovation methods and tools;
- A lack of best practices illustrating the effects in comparison to costs.

Regarding the second research question of this study (Q2), the barriers are indicated as hindering open innovation in clusters depended on the experience of cluster in supporting the OI activities. Main barriers to open innovation activities in clusters that were active in the OI area were difficulties in managing joint projects and enterprises' concerns regarding intellectual property rights. Potential loss of control over resources may increase the need to protect the intellectual property of the parties involved [62]. The results were confirmed in the qualitative analysis in selected cases. The importance of barriers significantly decreased with the direct participation of companies in joint innovative projects in the cluster, member companies learning about the experiences of other companies from the cluster undertaking such activities, and the development of detailed solutions for intellectual property rights. Model solutions introduced by experienced clusters, e.g., model contract, availability of an IPR specializing lawyer, and a specific process of defining the usage of the project results, seem to reduce the significance of the IPR barrier, though not completely eliminating it. Dissemination of these specific solutions in other clusters would probably reduce the significance of those barriers there as well. This calls for best practice exploring and disseminating good practices for the management of joint projects and securing intellectual property rights.

Clusters that did not introduce OI activities attached more importance to barriers related to lack of knowledge of open innovation tools and high costs of cooperation (which barriers are much less important for clusters that actually undertake OI activities). This may be related to internal factors of initiatives themselves, e.g., coordination problems or path dependency in some regions. It may also indicate that barriers preventing clusters from supporting activity related to OI do not have to be actual open innovation problems, but rather they are perceived as such by coordinators and cluster members, when in fact they relate to their innovation activity in a general sense [63]. This may be an indication of the overestimation of the importance of the costs of undertaking open innovation and the lack of sufficient knowledge on effective management of joint projects. Support for clusters in accessing trainings about the OI tools and methods and highlighting best practice examples in each cluster/industry may contribute to reducing the significance of the above barriers and making better use of opportunities related to open innovations in clusters.

Conclusions from case studies confirm the low activity of a large group of companies in clusters in initiating and looking for opportunities for innovation cooperation. This might be related to their technological and organizational potential, as well as the ability to absorb knowledge from outside and translate it into innovative products available to recipients. According to various literature streams dealing with innovation management, there is both a low capacity for absorption and resource constraints for significant barriers to innovation per se and not specifically to open innovation [33,34,64]. A better understanding of open innovation processes in SMEs therefore remains necessary, especially

in order to enhance the understanding of the challenges for establishing successful open innovation partnerships [65].

Open innovation in clusters seems to be characterized by the active and direct role taken on by the cluster coordinators resulting in a very hands-on approach to specific open innovation processes. Such clusters fulfill the role, outlined by Chesbrough et al. [4], as open innovation intermediaries, which actively combine new solutions, ideas, and talent, and which may, on this basis, enable innovation within other organizations [66]. Within public policy, such intermediaries should be regarded as critical agents, offering a far greater societal value than the value which they present to companies.

The findings of the study seem to point to the critical importance of support for this type of activity in clusters by regional and central administration. Clusters fulfill the public role as an intermediary of an innovation cooperation and a potential central element of a fourth industrial revolution ecosystem, but the need to finance open innovation activities from very limited resources of their member contributions means that they must limit their activities in this area. Models of financing innovative activity in transition economies, such as Poland, include very weak incentives for open innovation cooperation, compared to the developed countries and their cluster policies [67,68].

The initiatives selected as case studies operate at a high level, support dozens of enterprises in innovation activities, and based on the models and competences developed by them, it can be expected that by receiving the appropriate support, they would achieve even better results in opening the innovation processes of companies from the SME sector. Support for coordinators and the promotion of tools and methods as well as good practices related to undertaking OIs in clusters seems to be a rational solution here. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

6. Conclusions

The findings of the study provide an insight into the barriers faced by clusters as open innovation intermediaries. This article has argued that the concept of open innovation, as it was originally coined, and as it has been applied by clusters, can become one of the pillars for implementing the concept of the fourth industrial revolution [68]. For companies, it is often necessary to eschew familiar management styles in favor of a non-traditional method—instead of attempting to control knowledge, actors need to acknowledge and manage the ecosystem within which they can co-innovate [69,70]. A successful transformation requires conditions inherent in clusters—mutual trust, compatibility, close cooperation, and common principles. The specificity of clusters as a combination of competing and cooperating companies seems to fit well in such a framework.

This paper is a significant contribution to the OI knowledge related to open innovation in clusters, providing an indication of the degree to which clusters face barriers in supporting open innovation and how they deal with those barriers. The mere fact of cooperation between enterprises within clusters does not prejudge the success of joint innovative projects. Nonetheless, engaging in open innovation at cluster level seems to multiply the chance for this success through strategic and operational support in this difficult process, but it faces many barriers. The use of proven methods and tools of open innovation seems to facilitate setting open innovation cooperation among companies that have not yet undertaken it or face specific constrains, in particular SMEs. The above conclusions provide arguments and justify the creation of a systemic support for open innovation activity in clusters.

Even though these findings carry ramifications for policymakers in many regions, our analysis took into consideration that not all regions are distinguished by the same conditions. This study adopted a contextual view indicating considerable diversity across clusters in terms of open innovation processes and barriers thereto. This diversity indicates that path dependency will always affect cluster development since it is a highly contextualized process. Consequently, place-based policies specific to each region will be required to reflect local conditions.

The contribution of this multi-stage exploratory study to the literature is expressed in providing knowledge about the open innovation phenomenon present in an economic reality. The study magnifies

the modalities of open innovation in clusters, and, therefore, the findings are generalizable in this specific context. The study also provides important grounds for international comparisons, pointing to the specific conditions of the phenomenon for transition economies. The practical plane of this study includes providing knowledge on how to overcome barriers hindering open innovations in clusters, which can become a basis for recommendations both for the practice of coordinating innovative activities in clusters, but also for planning evidence-based economic policy.

The limitation of the study lies primarily in the size of the sample. The process of cluster development in Poland has started relatively recently, and the lack of a coherent cluster policy has limited the size of available research samples. Moreover, although the analysis takes it into account, the results are based on the viewpoints of the cluster coordinators and selected actors from OI active clusters in the transition economy context. Therefore, generalizations could be possible only where sufficient future studies have been carried out on more cases in different contexts.

This study could be instrumental to an understanding of the place-based aspects of open innovation and it is the hope of the authors that it will encourage further study into the role of clusters in the era of the fourth industrial revolution. This is especially relevant as research is currently hindered by several factors, notably a lack of official classification of practices pertaining to open innovation.

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Article

Buyer–Supplier Contract Length and the Innovation of Supplier Firms

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Abstract: The relationship with customers has important implications for operating decisions as well as firm performance. One important aspect of the supplier–buyer relationship is the contract duration, and how this factor is likely to affect firm investments has been under-researched. This study aims to investigate whether corporate innovation is linked to the maturity of contracts between suppliers and buyers. Using a sample of 1516 manufacturing firms in Vietnam for the period of 2014 to 2018, we find that longer-term contracts are positively related to firm propensity of innovation. However, only contracts with foreign purchasers have this characteristic, confirming the supportive role of foreign partners in uplifting the technology for domestic suppliers in a developing country. Interestingly, longer contracts do not tend to facilitate firm innovation or raise the aimed level of newness for firms with very long contracts compared with those that have short-term contracts. This is consistent with the agency cost theory. These findings are robust to different specifications and econometric approaches. Based on the findings, implications are provided to manage the relationship with customers more efficiently.

Keywords: contract length; firm innovation; agency cost theory; manufacturing firms

1. Introduction

There are different costs and benefits associated with contracts of various lengths between buyer and seller, and the choice can be challenging at times [1]. Long-term contracts facilitate the information exchanges between the two, allow the monitoring of production, and reducing costs embedded with frequent contract rebidding. Furthermore, long-term contracts are conducive to the mutual cooperation and efforts between the buyer and seller, which enhances the potential for the reduction in costs and time for product production [1]. Thanks to a long relationship with customers, the seller could receive more constant feedback and be able to identify trends, which is the prerequisite to innovation and to offering better services/products to the customer [2,3]. This is important as innovation is a complicated process that influences several types of stakeholders, and it can provide substantial benefits to upgrade the performance of both manufacturing and services firms [4–6].

Long-term contracts possess a clear advantage over short-term ones: risk-averse managers can demand a fixed price for a certain period under the contract in the context of high volatility in the market [1]. Nonetheless, contracts that specify such a condition tend to require a fixed investment beforehand. This type of investment can include the audit of the technical efficiency and financial ability of the supplier, and in certain cases require the buyer's aids in building up the technology and capital capacity to match the specific requirements of the buyer [1,7].

On the other hand, short-term contractual engagement can be preferred by risk-loving managers, as a speculative advantage is obtained by properly predicting the market price for the products or services. Furthermore, the seller can have the flexibility in approaching and offering the merchandise to other buyers, rather than having to commit to a fixed price in a specified period. As a result, Cohen [1] puts forward that managers need to weigh up the pros and cons between the advantages of hedging against price uncertainty and mutual cooperation that facilitates learning and better production efficiency attached to long-term contracts, and the flexibility and low upfront investments that short-term contracts offer.

Apart from the rationales related to operational optimization in the choice of contract length, the issue of agency cost can also matter. Feess et al. [8] argue that the agents could have different incentives and thus respond differently when faced with changes in the contract length. Expectedly, long-term contracts are prone to introduce the principal-agent problem. In the context of the buyer–seller relationship as discussed in this paper, the principal is the buyer while the seller is the agent contracted to perform the task of producing a product/service. Viewed under another perspective, the manager of the supplier firm (the agent) can receive the benefit of long-term contracts with the purchaser, reducing the incentive to innovate and destroying the firm owner's (the principal's) value. According to Sappington [9], the agent must be motivated to deliver excellent tasks as the principal would expect, because monitoring all the activities of the agent is not possible and prohibitively costly. Consistently, Kloyer et al. [10] are convinced that moral hazard can have a dragging effect on the efficiency of research and development, and Bao et al. [11] find that trust and contracts matter for the product innovation of manufacturers.

With regard to contract length-related literature, extant studies based on agency theory tend to examine the performance of the contracted athletes in sporting fields or managerial performance. Specifically, workers or athletes whose compensation and employment security are performance-based have a stronger incentive to exercise their full efforts [8,12]. This is no longer the case once job security or compensation does not depend on performance, and one of the situations is when the agent has obtained a long-term contract. The contract with longer coverage helps secure income, thus lowering the meaning of the agent's effort spent on the task. Moreover, workers can be less concerned about the employer assessment of their productivity when the contract maturity is long [13]. In the realm of corporate investment decisions, agency problems imply that once the seller firm has obtained a long-term contract that secures income in a competitive market, the incentive changes towards innovation in order to enhance production efficiency or towards making research and development expenditures to differentiate their products.

The motivation behind this study is to examine the principal-agent problem in the context of corporate innovation. Studies have found the formality level of contracts could affect the innovation efficiency [14]. In addition, the agency issue associated with the maturity of a contract has been excessively investigated with regard to the performance of athletes or workers or managers (the agents) when they are hired with long-term contracts by the owner of the club or firm (the principals), respectively. Nevertheless, the link between contract length and firm innovation between supplier and buyer has not been studied previously.

The remaining sections of the study include discussion on the relevant literature on the link between contract length and firm innovation. Section 3 details the research methodology where we build hypotheses and empirical strategies to test the hypotheses. Section 4 presents the empirical results and Section 5 concludes the paper with implications and directions for future studies.

2. Literature Review and Hypothesis Development

When engaging in a transaction, buyers and sellers are not only concerned about the identity of the partner, but also the length of the transaction. A simple model of the decision by seller and buyer in two periods can easily highlight the pros and cons of a long-term contract [15]. Trade is assumed to be efficient and beneficial in the first period, and what is unknown is the trade outcome

in the second period. If trade is also efficient in the later period, a long-term contract should be put in place. On the other hand, if trade is inefficient afterwards, a short-term contract mandating trade only in the first period is better. Nonetheless, the outcome in the second period is uncertain, thus both short-term and long-term contracts are not likely to be optimal. This simple framework explains why a short-term or a long-term contract is not always efficient, and contract duration needs to vary case by case. Interestingly, MacLeod and Malcomson [16] and Segal [17] suggest that no contract can be as effective as a sophisticated contract.

2.1. Contract Length and Firm Innovation

Stable customers help enhance firm performance and value [18,19], and long-term contracts have various advantages over short-term ones. Long-term contracts facilitate more frequent information exchanges between the two parties and allow close monitoring of the production process. The idea that customers can support in generating ideas to improve the firm's products and services has been increasingly supported, and insights related to customer characteristics are essential to the design of products and services and to guide innovative activities [20,21]. Ko et al. [22] opine that competent customer relationship management can efficiently support firm innovation through the efficient extraction and handling of customer-related information. Porter [2] stresses that strong relationships with the buyer assist firms in exchanging information between the two, and once the customer-related information can flow without being barricaded, innovation is facilitated. Dubois and Vukina [23] cited a message from a company to its growers, stating that the firm believes that contracts with a longer maturity would improve the trust and knowledge between the firm and its growers. Through this case study and additional empirical tactics, Dubois and Vukina [23] empirically confirm that as growers have longer contracts, their incentives to invest in human capital and to innovate are higher.

Furthermore, with long-term contracts, the costs entwined with frequent contract rebidding caused by short-term contracts should be lower [1]. Several sorts of costs are specified when the buyer needs to re-choose a supplier upon the expiration of a short-term contract: the identification of new and potential sellers, negotiation, determination of the seller and contract finalization [24]. Due to information asymmetry in the market, the sellers themselves also need to exert effort to signal their quality to find buyers. Coase [25] suggests that long-term contracts are introduced to avoid such costs, and argues that a two-year contract can reduce such ex-ante expenses by half compared to two one-year contracts.

Additionally, mutual cooperation and efforts between the buyer and seller can be facilitated through long-term relationships through long-term contracts, which enhances the potential for the reduction in costs and time for product production. Reviewing a large body of literature explaining the role of long-term contracts, Halonen-Akatwijuka and Hart [15] come to the conclusion that contracts with a long maturity are associated with more relationship-specific investments. In turn, these relationship-specific investments are made to offer unique products to the need of the buyer, thus making it costly and infeasible for the buyer to switch to substitute products [26]. A number of studies including Tan et al. [27], Chu et al. [28], Nunn [29], Kale and Shahrur [30] claim that innovation is necessary to meet customer's specific needs. Thanks to a long relationship with customers, the seller is able to receive more constant feedback and be able to identify trends as guidelines to the innovation to offer better services/products to the customer. Su and Bao [31] find evidence suggesting that total specific investment exerts a positive impact on the performance of innovation collaboration.

Cohen [1] specifically emphasizes the supplier–buyer cooperation as well as the incentive for the learning of a supplier as the chief advantages of a long-term contractual engagement between the two. As for the outcome of supplier learning, the improvement rate needs to be higher than a threshold value to validate the cost of specific investments associated with long-term contracts. What complicates this is the fact that the threshold value depends on a number of critical factors, including the initial fixed investment outlay, the risk preference of the manager and the market price volatility [1]. For example, highly risk-averse managers tend to value the ability to protect the firm against price uncertainty,

so they are more likely to be interested in long-term contracts even when the improvement rate is not high. Some researchers rely on a fixed cost assumption when writing a contract, and suggest a contract length chiefly by the level of uncertainty of the environment [32,33].

Pursuing a procurement bid, an efficient supplier with, perhaps, the lowest cost, is chosen, and a long-term contract is established to save the cost of frequent bids caused by shorter contracts. In a competitive market, shorter contracts allow the buyer to take speculative advantage and seek the current lowest-cost suppliers, thus reducing the price of inputs. Therefore, if transaction costs are not so high and the market is highly competitive, chances are the buyer would prefer to opt for short-term contract so that it can constantly switch to a new supplier with lowest-cost products at the moment [34]. In this market condition, long-term contracts can be highly valuable due to its ability to secure income stream for the supplier.

In a study by Baker et al. [35], it is expected that the economic uncertainty induced by Covid-19 is likely to lead to large output shrinkages. Especially, the economic uncertainty causes a huge cut in innovation-related expenditures as well as other expenses to improve the management capability, thus further undermining the productivity at least in the short-term future. Several studies point out that innovation projects tend to be risky and unpredictable, and are suitable in the long run. Innovation is an effort that requires huge financial resources, and unfortunately as opposed to other general investment, the cost of financing innovation activities is likely to be higher [36–38]. This is due to the uncertain outcomes associated with research and development activities; in other words, inputs are spent without guaranteed advantageous outcomes, and possibly end up being sunk costs for the firm. Furthermore, R&D activities should be kept clandestine to ensure asset specificity [27]. Innovation activities are also found to lower earnings quality, exacerbating issues with information asymmetry [39]. Therefore, due to the riskiness, information asymmetry and uncertain outcomes associated with innovation activities, internal resources tend to be the main source for these activities [40,41].

Barrero et al. [42] show that, since innovative investments are irreversible and present in intangible forms, they are extremely sensitive to a state of uncertainty. It can be expected that long-term contracts, which are valuable to risk-averse managers, can be conducive to firm investment in the R&D compartment.

To summarize, in general, it is expected that long-term contracts have various advantages compared to short-term ones, and are more conducive to innovation. As a result, the following hypothesis is established:

Hypothesis 1 (H1). *Long-term contracts have a positive association with firm innovation.*

2.2. Non-Linear Relationship Between Contract Length and Firm Innovation

As mentioned earlier regarding the study of Cohen [1], there are conditions in which long-term contracts tend to be more favorable to firm innovation compared to short-term contracts. These are when the improvement rate and learning ability from long-term contracts are not high, and managers are quite risk-averse while market prices are volatile.

Diamond [43] believes that short-term contracts could be employed as a means to signal that the agent is of a high quality, and that it is willing to subject itself to regular renegotiations. This can also be explained using the agency theory: short-term contracts offer the buyers more flexibility to switch to other suppliers with better prices and services, so firms with high quality products at reasonable prices thanks to decent innovative capability are more confident in engaging in short-term contracts. On the contrary, firms that are less capable of maintaining competitive products due to inefficient investments in innovation or low a innovative effort may feel more safety in attaining a long-term contract with buyers.

Stiroh [13] finds that long contracts tend to undermine the importance of employer's assessment and perception of employee's ability; as a result, workers have been incentivized to work less hard once their contract is finalized. This is strongly consistent with the findings of Joskow [44] who finds

that risk aversion can be considered as the most important factor for athletes to strive for long-term contracts. This is because with longer contracts, athletes are less worried about the risk of being fired following the deterioration of their performance, at least during their contracted period.

Long-term contracts are found to be connected to a moral hazard effect, which leads to a negative relationship between contract duration and athlete performance on average [8,12]. These studies suggest that effort levels of athletes under long-term contracts are lower than those in short-term ones. Enhancing contract duration has been considered as a tool to protect the interest of agents, thus increasing agency costs [8,45].

Therefore, it is clear that long-term contracts offer several benefits, especially by offering investment and stable conditions for firms to invest in innovative activities. However, once the length of the contract is over a threshold, it is more likely to raise the agency cost, depriving the firm of the incentives to innovate. Too-long contracts tend to secure the firms from the surrounding uncertainty, restraining the firms from keeping pace with the development of technology. This pattern can be highly destructive in a competitive market where managers are required not to be entrenched and the costs of making inefficient decisions are high [46–49]. Overall, these arguments suggest a non-linear inverted U-shaped relationship between contract length and firm innovation.

Hypothesis 2 (H2). *Contract length has a non-linear inverted U-shaped relationship with corporate innovation.*

3. Research Methodology

This study seeks to void the gap of the link between contract length and firm innovation by employing data from surveys conducted by the General Office of Statistics on manufacturing firms in Vietnam during the period from 2014 to 2018. There are two datasets in the present study. The first dataset is on the general characteristics of the firms such as total assets, total debt and profitability. These general surveys were conducted on a large number of firms in each year, e.g., in 2014 over 400,000, while in 2018, over 600,000 firms. The second dataset provides information on the technology adoption by a fraction of the firms in the first dataset. The information contained covers several important aspects including the average duration of contracts with foreign customers and with domestic customers, and Research and Development expenditures and the number of technological adjustments during each year. The second dataset is obtained from the surveys specialized in the technology adoption on a sample of about 5000 firms out of a much larger number in the general surveys mentioned above. The two datasets are merged using a tax code as the key variable to obtain variables covering both general characteristics and technology adoption of manufacturing firms in Vietnam. Filtering missing observations leaves us with a final sample of 1516 manufacturing firms over the period of 2014–2018.

As for empirical models, we rely on the following model to investigate the impact of contract length on firm propensity to innovate:

$$log\left(\frac{p}{1-p}\right) = \beta_1 con\_len + \beta_2 size + \beta_3 lev + \beta_4 roa + \beta_5 techtran + \beta_6 export + \beta_7 cust\_no$$

where: *inno* is the response variable, receiving the value of 1 if the firm responds Yes to the question of whether it conducted research and development activities in the considered year, and 0 otherwise. P is the probability of innovation being conducted for given values of a vector of explanatory variables, or the probability of the *inno* variable receiving the value of 1. Since the binary dependent variable (*inno*) has only two values, which are 0 and 1, we employ logistic regression for panel data. This is because when the response variable is a binary variable, it is not appropriate to apply conventional Ordinary Least Squares (OLS) regression or other regression techniques that assume the distribution of the error term follows a normal one. Instead, logistic distribution is applied to ascertain the validity of the statistical inferences.

Con_len is the main explanatory variable of interest, measured by the average length of all the contracts with foreign customers (con_len_foreign) and domestic customers (con_len_domestic). Size is

the firm size, measured by the natural logarithm of the firm's total assets [50]. Large firms tend to have more resources available for risky and resources-consuming activities like innovation. Lev represents firm leverage, measured by the ratio of total debt to total assets. Firms that engage in innovation activities are riskier, and a higher leverage could boost the firm' risk level; in other words, more debt can result in a firm's lowered incentive to conduct innovation. ROA indicates firm profitability, measured by the ratio of income to total assets [50]. Firms with a higher profitability can generate more internal resources that are supportive of innovation. Techtran is a dummy variable indicating whether most of the contracts with customers involve a technological transfer, receiving the value of 1 if Yes and 0 otherwise. Technology transfer from international partners is a critical source for technological spillover in developing countries [51]. Export is the percentage of the total sales that is exported. Trade can trigger technology spillovers [52] and the innovation of exporters can respond positively to the competition in the export markets [53]. Bauer et al. [54] show that to adapt to international markets, firms need an efficient product market development ability, or a strong innovation capability. However, exports can have a non-linear effect on a domestic firm's innovation [55]. Cust_no is the number of customers that buy the most important product of the firms. The concentration of a customer base could have a negative effect on a firm's R&D investment [27].

Using panel logistic regression, we estimate the research model with con_len being the contract duration for both foreign customers and domestic customers, in order to find out whether the impact of contract length on the propensity to engage in innovation activities differs between the cases of foreign and domestic buyers. We seek to improve the robustness of the findings by replacing the variable of innovation by the number of successful technological adjustments where we apply a fixed effects model to estimate. In addition, we split the sample into different subsamples based on the contract duration to test the robustness of whether short- and long-term contracts can assert a different impact on firm innovation. Finally, we provide another robustness check by investigating the ability of contract length to raise the willingness to aim for a higher level of newness in innovation, as a test of the ability of contract duration in dealing with agency cost.

4. Results and Discussions

4.1. Descriptive Statistics

Table 1 provides descriptive statistics about the variables in the model. The *inno* variable has the average value of 0.089, indicating that about 9% of the observations engaged in innovation. The variable of contract length for foreign customers (con_len_foreign) is about 6.5 months, while that for domestic customers (con_len_domestic) is 8.5 months. It should be noted that these values are derived by taking the average of all the observations in the sample. However, when separately calculating the average value for the firms that have foreign customers, the average contract length is 9.2. The size of the firms in the sample is much smaller than the listed ones in Vietnam, thus implying their constraints in accessing external funding sources. The leverage ratio is about 54 per cent, indicating a high debt ratio so firms could meet difficulty in borrowing more to finance innovation activities, while ROA is only 4.7%, lower than that of the listed ones. About 11 per cent of the observations involved technology transfer associated with the contracts. The ratio of export to total sales is about above one third of the total sales. Finally, the average number of customers that buy the main product of the firm is 3.6.

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
inno	8552	0.089	0.285	0.000	1.000
con_len_domestic	8552	8.526	6.031	0.000	48.000
con_len_foreign	8552	6.447	6.752	0.000	80.000
size	8552	11.352	1.606	2.485	17.297
lev	8552	0.543	0.262	0.000	0.980
roa	8489	0.047	0.111	−0.568	0.631
techtran	8503	0.107	0.309	0.000	1.000
export	8552	37.375	38.942	0.000	100.000
cust_no	8551	3.654	1.329	0.000	5.000

Source: Author's calculation from research dataset.

Table 2 provides pairwise correlation coefficients of the variables in the model. Accordingly, both *con_len_domestic* and con_len_foreign have positive and significant coefficients with *inno*, suggesting that longer-term contracts tend to facilitate innovation activities. It should be noted that the coefficient and significance level of con_len_foreign are much higher than those of con_len_domestic, suggesting that while contract term has a positive effect on innovation, contract term with foreign customers tends to lead to more investment in research and development. Larger firms are more likely to conduct innovation, while more debt seems to put a barricade on this activity of the firms. *ROA* has a positive and significant correlation on innovation, suggesting that more profitable firms are able to earmark more resources to innovate. More customers for the main product increase the propensity to innovate for the firms. Finally, firms with more share of revenue from export have less incentive to conduct innovation activities.

Table 2. Correlation matrix.

	Inno	Con1	Con2	Size	Lev	Roa	Techtran	Export	Cust_No
inno	1.000								
con1	0.021 **	1.000							
con2	0.034 ***	0.231 ***	1.000						
size	0.129 ***	0.067 ***	0.252 ***	1.000					
lev	−0.029 ***	−0.043 ***	−0.038 ***	0.065 ***	1.000				
roa	0.059 ***	0.088 ***	0.125 ***	0.221 ***	−0.240 ***	1.000			
techtran	0.147 ***	0.045 ***	0.030 ***	0.093 ***	0.002	0.015	1.000		
export	−0.044 ***	−0.217 ***	0.414 ***	0.176 ***	0.023 **	−0.015	−0.034 ***	1.000	
cust_no	0.085 ***	0.131 ***	−0.069 ***	0.218 ***	0.007	0.093 ***	0.032 ***	−0.292 ***	1.000

Source: Author's calculation from research dataset. The bolded numbers below are *p*-values. Con1 is con_len_domestic, and Con2 is con_len_foreign. Size represents the size of the firm; Lev is the ratio of total debt to total assets; ROA is the profitability measure of the firm; Techtran is a dummy variable indicating whether most of buyer-purchaser contracts involve technology transfer; Export is the ratio of export sales to total sales; Cust_no is the number of the customers that buy the firm's main products. *, **, and *** denote significance at 10%, 5% and 1%, respectively.

4.2. Results and Discussion

Table 3 presents the results of the panel logistic regression. Contract length for foreign customers is significantly and positively related to innovation activities. On the contrary, contract length for domestic buyers has an insignificant impact on the propensity of firms to innovate. Estimating the model with both of these variables also yields similar results, confirming the advantage of contract duration with foreign customers over domestic ones. The patterns are in line with Hypothesis 1, which suggests that longer maturity creates favorable conditions for firms to innovate. These results are consistent with the argument that in a competitive market, having secured the income stream for a period of time allows firms to have more resources to do research and upgrade technology, and long-term contracts also enable firms to extract insights from customers and continuous feedback, which effectively directs the innovation process [2]. Furthermore, innovation activities are costly

and risky and have a high level of information asymmetry, lowering the ability to access external financing. Once long-term contracts are signed, the buyer could make some specific investment so that the supplier is able produce specific merchandise that matches the requirements of the buyer [15], and such investments can relieve the supplier's constraints and increase close collaborations [26].

Table 3. Contract length and firm innovation.

Inno	Foreign		Domestic		Both	
con_len_foreign	0.046	***			0.053	***
	(0.012)				(0.013)	
con_len_domestic			−0.004		−0.023	
			(0.014)		(0.015)	
size	0.442	***	0.478	***	0.446	***
	(0.070)		(0.069)		(0.070)	
lev	−0.26		−0.335		−0.262	
	(0.353)		(0.351)		(0.353)	
roa	0.383		0.528		0.411	
	(0.792)		(0.788)		(0.793)	
techtran	1.795	***	1.768	***	1.802	***
	(0.213)		(0.212)		(0.213)	
export	−0.008	***	−0.005	*	−0.009	***
	(0.003)		(0.003)		(0.003)	
cust_no	0.154	**	0.148	**	0.159	**
	(0.073)		(0.072)		(0.073)	
_cons	−11.754	***	−11.783	***	−11.606	***
	(0.824)		(0.823)		(0.829)	
No of obs	8442		8442		8442	

Source: Author's calculation from research dataset. *, ** and *** denote significance at 10%, 5% and 1%, respectively.

One more interesting finding is that contracts with foreign customers appear to be more beneficial in terms of facilitating corporate innovation. This result is consistent with the view that in a developing economy with fledgling financial markets and inadequate institutions, firms have more difficulty in receiving funding for innovation activities, and that the technology sources coming from foreign direct investment (FDI) and foreign partners are essential to drive the innovation level [56,57]. Therefore, only long-term contracts with foreigners are prone to deliver a favorable effect on firm innovation.

We provide a robustness check to the result in Table 3 by replacing the dependent variable (*inno*) to represent the number of successful technological adjustments during the year. As the variable is not a binary one anymore, we rely on a fixed effects estimation technique. This variable can dictate the innovation effort of a firm through adjusting technology to match the new competitive conditions or corporate requirements. In Table 4, it is clear that the results are the same for the sign and the significance of the variables of con_len_foreign and con_len_domestic. In particular, con_len_foreign has a positive and significant correlation with the number of successful adjustments. On the other hand, *con_len_domestic* is not significant. These results again confirm the advantage of long-term contracts with foreign buyers in lifting the ability to innovate, consistent with Oum et al. [56] and Bozic and Rajh [57].

Table 4. Contract length and the number of successful technological adjustments.

No of Adjustments	Foreign		Domestic		Both	
con_len_foreign	0.033	***			0.034	***
	(0.006)				(0.006)	
con_len_domestic			0.003		−0.002	
			(0.006)		(0.006)	
size	−0.085		−0.081		−0.085	
	(0.067)		(0.067)		(0.067)	
lev	0.188		0.186		0.189	
	(0.145)		(0.146)		(0.145)	
roa	−0.022		−0.02		−0.021	
	(0.279)		(0.280)		(0.279)	
techtran	0.248	**	0.245	**	0.249	**
	(0.098)		(0.098)		(0.098)	
export	0.003		0.006	***	0.003	
	(0.002)		(0.002)		(0.002)	
cust_no	0.058	*	0.06	*	0.058	*
	(0.034)		(0.034)		(0.034)	
_cons	0.862		0.892		0.871	
	(0.738)		(0.742)		(0.739)	
r2	0.013		0.005		0.013	
No of obs	6371		6371		6371	

Source: Author's calculation from research dataset. *, ** and *** denote significance at 10%, 5% and 1%, respectively.

We proceed with the test of Hypothesis 2 about the non-linear effect of contract duration on firm propensity to innovate. The research sample is split based on the median value of the contract duration for each type of customer (foreign or domestic). In Table 5, we see that again the longer contract duration with foreign buyers enhances the ability of the firm to innovate, while it is not so favorable in the case of domestic purchasers.

With regard to foreign partners, it is clear that the coefficient of con_len_foreign for firms with shorter-than-median duration contracts is much larger than for those with longer-than-median duration. Moreover, for domestic partners, the negative effect of a contract length on firm innovation only exists for firms with contracts of longer-than-median duration. These patterns clearly indicate that even though in general firm innovation propensity raises as contract length increases, firms with too-long contracts can have lower incentives to engage in research and development departments. This is consistent with the prediction under Hypothesis 2.

The less favorable impact of contract duration when firms have too long contracts is in line with the agency cost theory, which predicts that when agents have secured an income for a prolonged period, incentives to exert efforts in updating technology and improving efficiency are lower. Extant literature examining the influence of contract duration on athlete performance also supports the view that long-term contracts can undermine athlete performance, compared to short-term ones [8,12,45]. Long-term contracts have several merits over their short-term counterparts, including the feedback and insights from customers, relationship-specific investments that provide technology and financial support, and uncertainty mitigation which spurs innovation. Nonetheless, too-long contracts could shield firms from the risk of uncertainty and strong competition in the market, which may discourage firms from maintaining their innovation level. To some extent, the non-linear effect in this study also provides evidence in support of the signaling tool of short-term contracts [43].

Table 5. Impact of contract length and firm innovation—subsamples.

inno	Foreign Buyer_Long Contract		Foreign Buyer_Short Contract		Domestic Buyer_Long Contract		Domestic Buyer_Short Contract	
con_len_foreign	0.048	***	0.367	***				
	(0.017)		(0.123)					
con_len_domestic					−0.064	*	−0.058	
					(0.035)		(0.066)	
size	0.369	***	0.453	***	0.53	***	0.454	***
	(0.101)		(0.101)		(0.092)		(0.111)	
lev	0.26		−1.026	*	0.233		−0.992	*
	(0.500)		(0.542)		(0.476)		(0.565)	
roa	1.369		−1.149		1.782	*	−0.307	
	(1.080)		(1.336)		(1.041)		(1.306)	
techtran	1.982	***	2.172	***	1.97	***	1.793	***
	(0.306)		(0.344)		(0.283)		(0.384)	
export	−0.017	***	−0.009	*	0.001		−0.011	***
	(0.004)		(0.006)		(0.004)		(0.004)	
cust_no	0.088		0.24	**	0.322	***	0.039	
	(0.104)		(0.112)		(0.101)		(0.117)	
_cons	−11.163	***	−12.541	***	−13.079	***	−10.665	***
	(1.280)		(1.147)		(1.224)		(1.285)	
No of obs	4268		4174		4755		3687	

Source: Author's calculation from research dataset. *, ** and *** denote significance at 10%, 5% and 1%, respectively.

In Table 6, again we replace the *inno* variable by the variable indicating the number of successful technological adjustments, while keeping other settings the same as in Table 5. We apply a fixed effects model to estimate the effect of contract duration on firm innovation. There are two important similarities in the results between Tables 5 and 6. First, contract duration only has a positive effect with foreign purchasers. Second, for foreign buyers, contract duration only enhances firms' propensity to engage in technological upgrades when under a certain threshold. These results clearly support Hypothesis 2 and the agency cost theory.

Table 6. Impact of contract length on the number of successful adjustments—subsamples.

No of Adjustments	Foreign Buyer_Long Contract		Foreign Buyer_Short Contract		Domestic Buyer_Long Contract		Domestic Buyer_Short Contract	
Con_Len_Foreign	0.028		0.788	***				
	(0.021)		(0.123)					
con_len_domestic					−0.044		0.067	
					(0.028)		(0.071)	
size	0.597	***	0.138		0.435	***	0.534	***
	(0.121)		(0.087)		(0.097)		(0.123)	
lev	0.782		0.126		0.561		−0.638	
	(0.538)		(0.444)		(0.469)		(0.587)	
roa	−0.264		0.133		0.439		0.922	
	(1.138)		(1.124)		(1.073)		(1.384)	
techtran	1.909	***	1.345	***	1.703	***	1.836	***
	(0.395)		(0.321)		(0.312)		(0.506)	
export	−0.009	**	−0.005		0.022	***	0.004	
	(0.005)		(0.005)		(0.004)		(0.005)	
cust_no	0.067		0.231	**	0.2	**	0.129	
	(0.116)		(0.096)		(0.100)		(0.135)	
_cons	−11.855	***	−7.68	***	−10.783	***	−14.153	***
	(1.508)		(0.953)		(1.177)		(1.343)	
No of obs	2750		3621		3470		2901	

Source: Author's calculation from research dataset. *, ** and *** denote significance at 10%, 5% and 1%, respectively.

Table 7 provides our last specification investigating the potential benefit of contract duration under a certain threshold. We introduce the aimed level of newness as a proxy for innovation effort and find that only firms that have contracted with international buyers have more incentives to conduct radical innovations or upgrades that are not meant to be incremental. We use ordered logistic regression for panel data to estimate the model since the dependent variable has 3 values: 1 indicating the desire to create products/processes that are new at the firm level, 2 indicating the same item at the country level and 3 aiming at international level. The contract length with domestic purchasers does not impose a significant impact on firm desire to aim for a higher level of innovation newness.

Table 7. Contract length and the aimed level of newness.

Level of Newness	Foreign Buyer_Long Contract		Foreign Buyer_Short Contract		Domestic Buyer_Long Contract		Domestic Buyer_Short Contract	
con_len_foreign	0.071	***	0.929	***				
	(0.027)		(0.157)					
con_len_domestic					−0.020		0.033	
					(0.041)		(0.081)	
size	0.536	***	0.578	***	0.814	***	0.546	***
	(0.167)		(0.129)		(0.124)		(0.134)	
lev	0.724		−0.813		0.272		−0.845	
	(0.723)		(0.649)		(0.585)		(0.648)	
roa	2.522		−0.159		3.206	**	0.145	
	(1.595)		(1.524)		(1.345)		(1.499)	
techtran	1.977	***	1.96	***	1.463	***	1.369	***
	(0.443)		(0.391)		(0.341)		(0.461)	
export	−0.033	***	−0.012	*	0.014	***	−0.005	
	(0.006)		(0.007)		(0.005)		(0.005)	
_cons	132.032	***	22.859	***	37.492	***	39.887	***
	(37.622)		(6.003)		(8.930)		(12.716)	
No of obs	2071		3347		2891		2527	

Source: Author's calculation from research dataset. *, ** and *** denote significance at 10%, 5% and 1%, respectively.

With regard to foreign buyers, contract length generally increases the motivation to innovate further and desire to create a radically new product/service/process. One particular noteworthy result is that longer contracts tend to have more impetus on firms to obtain radical innovation when under a certain threshold (under median duration in this study), as shown by the significantly lower coefficient in the sample with higher-than-median contracts compared to that of lower-than-median contracts. This further robustness check provides strong evidence to ascertain the more negative effect of contract length once over a certain threshold as a result of a potential agency issue.

5. Conclusions and Discussion on Buyer-Supplier Contract Length and Open Innovation

Previous literature has discussed the relationship between contracts and agents' performance, both at individual and corporate levels. The main focus of prior studies is on the link between contract duration and athletes' performance, and whether manager's contract duration affects firm investment and performance. Nonetheless, the relationship between the length of contract with buyers and firm innovation has not been dealt with, even though the several aspects of the link between customers and firms have been examined.

This study aims to void the gap by using data from the surveys conducted by General Office of Statistics in Vietnam for a period from 2014–2018, covering a wide range of financial indicators and technology adoption patterns. In the present article, we aim to investigate the impact of contract duration with (foreign and domestic) buyers on the firms' propensity to engage in innovation. The dependent variables indicate whether firms conducted research and development and the number of successful technological adjustments.

Using logistic regression for panel data, we find that contracts with a longer term in general increase firm likelihood to perform innovation. This result is in line with the view that long-term contracts offer income security, promote more frequent feedback and information with customers and technology transfer and mutual collaboration. All of these commendable features create conditions conducive to technology upgrades and advancement. However, not all long-term contracts are beneficial to firm innovation, and only those with foreign buyers appear to be the sole driver for firms' technological updates. This result supports the argument that firms in developing countries tend to lack resources for risky and opaque innovation activities, thus the support and liaison with international corporations as buyers play an important role in encouraging supplier firms to do research. Previous literature only discusses the role of the participation of foreign partners in domestic firms' research and development, while the present paper provides evidence specifying one channel explaining that desirable effect: foreign partners, rather than domestic ones, are more capable of creating conditions for their suppliers to conduct innovative activities with their long-term contracts.

Furthermore, we find that longer term contracts do not always lead to a better incentive to innovate. The findings suggest that as the length of the contract surpasses a certain threshold, longer maturity of the contract is more likely to be associated with a higher agency cost, thus lowering the willingness to innovate. On the other hand, under a certain threshold, contract duration is positively related to firm innovation. This result is consistent with previous studies that focus on the negative link between contract duration and athlete performance, and extends the literature by examining this linkage in the context of corporate performance. This extension is important as the non-linear relationship has never been empirically examined before, while it should provide important implications for customer and investment management.

Open innovation can have complex effects on firm performance depending on a number of factors. Firstly, it may depend on how firms access knowledge from external channels. Chiang and Hung [58] suggest that open search depth, or utilizing knowledge from a restricted number of external sources, is bound to facilitate incremental innovation. On the other hand, open search breadth, or obtaining knowledge from a wide range of external sources, are more likely to trigger firms' radical innovations. This is consistent with the view of March [59], showing that broader knowledge searches may induce higher levels of exploratory organizational learning. For macro factors, Yun et al. [60] find that a global financial crisis can have a moderating effect on the link between open innovation and the performance of SMEs. Furthermore, Yun and Liu [61] point out the micro- and macro-dynamics of open innovation together with the changing roles of different stakeholders in sustainability matters.

In addition to the number and depth of the channels of external knowledge sources, the efficiency of open innovation may also be affected by the organizational modes. Bianchi et al. [62] find that different collaboration modes, e.g., licensing agreements and the provision of technical and scientific services, are used with different categories of partners (e.g., universities, product biotech companies). The effect of such complicated choices on firm performance provides potential venues for future studies.

Yun et al. [63] show that culture can be a critical driver of open innovation. According to this research, culture affects open innovation under different perspectives, namely entrepreneurship, intrapreneurship and organizational entrepreneurship. The authors point out that societies benefit from a culture that is cultivated for boosting open innovation; even for the public sector. Yun et al. [64] argue that a cooperation between governments and firms is needed to sustain conditions for open innovation in the market. To encourage a firm to participate in innovation, support in different forms need to be administered by the government.

Most SMEs are resource-constrained; therefore, they need to focus on their existing business to attain greater efficiency, thus being unable to diversify their businesses [65]. SMEs that lever on open innovation are able to access external resources of their open innovation partners, and this allows them to be engaged in diversification strategies. Nonetheless, Colombo et al. [66] opine that SMEs are not always willing as well as capable of utilizing an open innovation strategy, and this warrants further research on open innovation for SMEs.

The implications of our study are two-fold. First, firms in developing countries can utilize the partnership with foreign purchasers to be able to learn and update the formers' technologies in a more effective manner. This study confirms the role of the access to external resources of innovation partners, but emphasizes more on the importance of international partners, rather than domestic ones. Extending Bianchi et al. [62], we provide insights into another cooperation mode, i.e., supplier–buyer relationships, that benefits firms in terms of innovative activities. Second, the study offers evidence that requires the management to be vigilant and to stay posted with the current technological development even when the firms have secured long-term contracts with the buyers. Long-term contracts provide security in terms of revenue, but in a competitive market, too much complacency from such contracts might put the firms at risk of having outdated technology. The above findings are robust to several specifications and econometric methods. These results again confirm the complication of the effect of open innovation on firm performance, which requires careful investigation of other channels to harness the negative points and promote positive points of open innovation.

The limitations in the paper are that we have not considered whether the governance characteristics of the firms can interfere with the relationship between contract length and firm open innovation, as well as whether the interaction between contract length and firm innovation can exert a significant impact on firm performance. Firm ownership and characteristics of board of directors are potential factors to study their moderating effect on the association between contract length and firms' research and development. Furthermore, the examination of the impact of contract duration and innovation on firm performance should provide evidence to check the robustness to this study, and offer a scientific base for corporate decision makers in terms of the management of customer relationship and innovation. Therefore, these should serve as highly potential venues for future research.

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Firm Constraints on the Link between Proactive Innovation, Open Innovation and Firm Performance

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Abstract: This study aims to examine the impacts of firm constraints and proactive innovation on firm performance, using a sample of 3504 small and medium enterprises (SMEs) in Vietnam from 2011–2015. Our findings suggest that technological innovations in general are beneficial to firm performance, increasing firm sales and profits. Further filtering innovations into two categories of proactive and reactive ones, we find that reactive innovation negatively affects firm performance, consistent with the view that proactive entrepreneurial behavior is a highly sought-after characteristic or a valuable resource for a firm as specified in resources-based theory. Finally, our result implies that if firms have low constraint or have sufficient resources, proactive strategies should be the choice if firms seek to improve their performance.

Keywords: technological innovation; proactive innovation; reactive innovation; firm performance; manufacturing industry

1. Introduction

Global economic integration is highly conducive to SMEs' operations, as it provides them with opportunities to adopt new technology and leverage on their business network [1]. Innovation has emerged as a crucial factor that helps firms to stay competitive and sustainable in the long run [2,3]. Firms are motivated to perform innovation on account of many reasons, especially in the form of proactive and profit-driven capital expenditure to improve efficiency and competitiveness, enabling them to enter new markets while securing the current market shares [4]. In other words, these motivations are proactively initiated by the firms themselves. However, there are other sources of motivations that are of coercive force, e.g., innovation in line with the requirements from customers, or from local or central governments regarding safety and environmental concerns. When firms adopt new technology or conduct innovations out of these reasons, their behavior is reactive [5].

The question of which approach, proactive or reactive, is more beneficial towards firm performance remains topical. Different scholars may evaluate these innovative orientations differently. Proactive innovations are effective tools for firms to constitute the first mover advantage in the market [6]. First movers are less likely to cease building and leveraging on their network with clients to incorporate into their business model, which is supposed to improve their performance [7]. In the same vein, the study of Robinson and Min [8] suggests that firms proactively entering the market have higher probability to survive, compared to their late-coming counterparts. These pieces of evidence radiate the merits and positive influence of proactive orientation on firm performance.

On the other hand, first-mover edge associated with proactive innovation approach could be inexistent, as in the case of an industry with low entry barriers [9] and low operating risks [10], because late comers could easily and quickly imitate the innovative outcome of the first mover. Other studies such as Baker and Sinkula [11] and Hong et al. [12] confirm that proactive orientation does not necessarily result in more innovative products. Similarly, as much as Gilbert and Allan [13] agree that reactive strategy could appear less dynamic and slow to respond to changes in the market place compared to proactive strategy, the latter is not always superior.

In addition to the issues of the inconsistent link between proactive innovation and firm performance, there arises a literature strand examining whether firm constraints exert impact on innovative performance. Innovative investments are risky and challenging due to their uncertain outcomes, exacerbating the information asymmetry and conflicts of interest with financers [14,15]. Besides financing constraint, SMEs could face other limitations such as the lack of privileged information from exports, technology and human resources, especially in developing economies. Due to these constraints, SMEs are bound to encounter more hurdles to innovations as opposed to their larger peers [16]. Because of their small scale, SMEs have encountered higher transaction costs, lower investment in Research & Development (R&D), insufficient knowhow and lack of networks, resulting in operational instability [17].

Iootty [18] discusses the conditions necessary for innovation to play a chief role in East Asian countries. These countries have been struggling to improve per capita income in spite of myriad of difficulties such as competitive pressure and severe lack of resources and capabilities to innovate [18]. Iootty [18] compares and contrasts the innovation patterns in two groups of countries and find that firms in developing countries innovate less than those in advanced countries, even when innovation yields high return for the former. This innovation paradox is caused by the existence of barriers in three main fronts, emphasizing the plight of firms in East Asian countries, especially Vietnam. The country has been shown to showcase top-notch innovative performance, even though the firms could perform much better if its firms had lower constraints.

As pointed out in the previous passage, SMEs face numerous potential constraints that determine SMEs' capability to innovate. Nonetheless, literature tends to focus on the lack of credit as a sole indicator of external constraints [19–22]. Studies that deal with other types of constraint tend to focus on firms in developed markets [23,24]. As a consequence, little is known about the linkage between constraints and innovative performance in developing countries. It seems unclear as to whether firms with low and high levels of constraints should choose proactive or reactive orientation. This leaves an interesting and significant research gap for firms in developing economies.

The present study aims to fill the above gap using SME data from Vietnam. This developing economy provides a suitable setting for a number of reasons. First, the growth of Vietnamese economy has been impressive since the early 1990s, and second, the rate of poverty reduction has been encouragingly unprecedented [3]. Yet, this encouragingly strong performance record is still far from the nation's full potentials [22], because the country can still increase the productivity growth through heavier investment and the uplifting of innovation capabilities. SMEs represent the major force, thus, improving the performance in this sector is meaningful [17]. The paper proceeds as follows. Section 2 discusses relevant theories and related empirical studies that provide the fabrics for the development of the hypotheses regarding the innovation performance, with and without constraint factors being considered. Section 3 describes the dataset and models to be estimated. Section 4 presents the estimations of the models, and the implications from the findings. Section 5 concludes the paper.

2. Literature Review

2.1. Relevant Theories

2.1.1. Resources-Based Theory

The theory most relevant in this paper is the resource-based view that theoretically addresses the determinants of firm's competitive advantage. This theory places an emphasis on the firm's resources heterogeneity, and seeks to answer how firms should deploy resources to attain and secure competitive advantage. Penrose [25] sets the foundation of the theory by considering a firm as a collection of resources, and that the heterogeneity of productivity derived from the resources differentiates firms from each other. Studying the characteristics of resources could provide useful insights for strategic management [26,27].

The strategic resources a firm owns are heterogeneous due to resource-market imperfections and resource immobility [28]. There are different classification schemes of resources in the firm. As Wernerfelt [27] described, each entity is a unique bundle of resources that could be both tangible and intangible. Kostopoulos et al. [26] suggested that financial or physical resources are tangible, while knowhow, human, technological and organizational resources (brand name, organizational procedures) are intangible.

Barney [28] provided another classification scheme based on the vital characteristics that resources should possess to secure or even expand firm's market shares. Initially, there are three important features: valuable, which means the resources should help the firms to suppress the threats as well as utilize opportunities from the market movements; rare, meaning that the resources are not popular and accessible to all existing and potential firms; inimitable, i.e., the resources are not easy to copy and non-substitutable. Following Barney's doctrine [28], later studies have expanded and supplemented with other desirable traits for resources, including durability, non-tradability and lastly heterogeneity [29,30].

Under the framework of resource-based theory, capabilities are also relevant and important. To some extent, a firm's advantage does not only rely on the resources, but the ability of the firm to maneuver among different resources [29]. The capabilities are basically intangible processes and unique to each firm and it requires time to develop to become efficient [29]. In fact, Kostopoulos et al. [26] argued that they are "intermediate goods", enabling the enhancement of productivity of the resources and being an indispensable part of strategic management.

Firms should have no content-free period in acquiring and upgrading their resources and capabilities to stay competitive in a market that never stops revolutionizing [31]. However, this requires firms to be able to trace back the originality of resources and capabilities. This problem has been underexplored in the literature [26], but there have been some internal sources identified, ranging from organizational exploration [32] to the role of leaders [33]. Additionally, there are external sources that can impact the way resources are obtained, selected and deployed. These include technological environment, market structure (which leads to different profiles of power between buyers and sellers) and competition [26]. In other words, industry and market factors, also known as strategic industry factors [29], should also play a key role in determining a firm's resources and capabilities.

2.1.2. Theory of Planned Behavior

According to Bird [34], intentionality is conducive to high achievements since it combines and directs an entity's attention, experience and behavior effectively. Intentionality prepares the firms to navigate through all changes, thus affecting firms' ability to survive and grow. In addition, a number of motivational factors that can influence behavior, such as the resolution and effort, can be captured by intentionality [34]. In the beginning of an innovation project, corporate intentions toward a behavior (the adoption of the innovation project) are affected by the firm's own assessment of feasibility and desirability of the project [35]. Intentions also help raise the confidence of the innovators [36]. Therefore, intentionality is important to the adoption of an innovation activity, as well as the positive outcome from the activity of a firm.

2.1.3. Pecking Order Theory

The pecking order theory posits that firms base deciding which funding sources to finance investments on a specific order of preferences. This is because firms are supposed to possess informational advantages compared to external stakeholders, when the firm risk does not emanate from observable macro-level sources such as exchange rate fluctuation or market turbulence, but is idiosyncratic to the very firm. The information asymmetry problem exacerbates the agency cost of external financing to an extent that firms are reluctant to use external funds, except when internal sources of financing have been depleted [37]. Secondly, if external financing is required, firms will favor debt over own equity.

In the realm of innovation, innovative firms are risky investments for investors [38]. They tend to heavily invest in research and development activities whose outcomes are technically uncertain (technology risk). Moreover, firms are unlikely to disclose fully the information about the innovation projects because this can encourage imitative reactions from competitors (value appropriation risk). Finally, even when the innovation is technically successful, it does not necessarily guarantee a great debut in the market place (market risk). As a consequence, firms are not willing to share information about the intended and likely outcomes of their investment opportunities to fund providers.

Under the framework of the pecking order theory, we can expect that innovative firms, which are highly risky, will be closely perused by the market. Because of the issues associated with asymmetric information, external finance for these firms can be provided only at a premium. Consequently, innovative firms may find it prohibitively expensive to rely on external finance.

2.2. Development of Hypotheses

2.2.1. Innovation and Firm Performance

Constantly upgraded technologies, changing customer tastes and shortening product life cycles coupled with increased global and regional competition have urged firms to innovate relentlessly [39]. Technologically, a firm could either improve its market products or services (product innovation) or the way these items are made (process innovation). Product innovation is mostly induced by demand factor, but supply side could also be a significant driver for this type of innovation in some cases [40]. Process innovation leads to improvements in the methods of production or delivery of products/services [41]. The process could be new or significantly improved compared to the existing version. A typical example is the changes in involved techniques, equipment or software used in producing or delivering goods/services to customers. These two types of innovation, both marginally and radically, are enabled by technological changes.

Many studies have documented the empirical positive link between technology-enabled innovation and firm performance. For example, van Beveren and Vandenbussche [42] examined the link between firm innovation and the ability to take part in abroad sales. Their findings suggest that more innovative firms, i.e., those with more product and process innovations, tend to sell their goods in overseas markets. Consistently, Gunday et al. [43] argued that both product and process innovations are likely to be associated with better corporate performance.

Other research works also compared the influence of product and process innovations on firm performance. Studies by Hall et al. [44] for Italian SMEs, Waheed [45] for firms in Bangladesh and Pakistan and Tuan et al. [46] for Vietnamese firms in supporting industry confirmed that process innovations are more prominent drivers of performance, compared to product innovations. On the other hand, Hall [47] found substantive evidence on the positive effect of product innovation on revenue, while process innovation effect is hazier. Fagerberg et al. [48] contended that new product introduction could exert a strongly positive effect on the growth of income and employment, whereas process innovation shows a more controversial effect probably due to an intrinsic feature of this innovation type is to reduce costs. Other studies such as Rosli and Sidek [49] for Malaysian firms, Tuan [50] for SMEs in manufacturing industry, Mairesse and Robin [51] for French firms and Cassiman et al. [52] posited that product innovations have more pronounced impact on firm performance, as opposed to

process counterpart. Griffith et al. [40] investigated innovative activities for a sample of firms in four European countries. These authors found that process innovation only helps increase productivity in France, while product innovation is more effective and raises productivity in France, Spain and the UK.

In summary, the conventional finding is that product and process innovations, in short technological innovations, tend to have positive effects on firm performance, though in some cases, product innovations were found to be more productive than its counterpart and vice versa. Innovations are important towards firm performance and survival, and consistent with the mainstream finding, the following hypothesis was established:

Hypothesis 1 (H1). *Technological innovation has a positive effect on firm performance.*

2.2.2. Proactive Technological Innovation and Firm Performance

Discussed previously, a firm's resources are a key factor to achieve competitive edge, and they could be either tangible or intangible [53]. Proactive entrepreneurial behavior is an intangible resource. Proactive behavior represents strong beliefs and great value placed on the importance of being a first mover to attain better performance [54]. Proactive orientation is the tendency to conduct innovations based on the anticipation of the market changes to grasp new opportunities [55]. Other studies, such as Nasution et al. [56] and Rhee et al. [57], stated that an SME's proactive behavior could even shape the trend in the market, rather than just follow it.

Based on the resources-performance linkage theory by Barney et al. [53], a direct and positive link relationship between proactive innovation and firm performance is expected [26]. Firms with a proactive orientation have a tendency to desire the status of a first mover in a competition and focus on seeking opportunities, thus, they are more likely to pool their resources for innovative activities [58]. If a firm attains first-mover status, it may face weak competition, since there should be very few or even no companies that offer similar products. The resulting outcome is that the products or services of proactive firms could meet business targets more easily.

Besides the direct resources-performance linkage, there could also be an indirect resources-performance, where proactive behavior affects performance through its impact on innovation capability. The resource-capability link suggests that proactive behavior improves a firm's capability [29]. In a firm's innovation context, proactive entrepreneurial behavior forms an organizational resource that guides the firms to concentrate on innovative programs in a bid to pursue market opportunities [55]. Through repeating these innovative programs, firms cultivate experience and obtain insights of how to conduct such programs more efficiently, ultimately upgrading capability [59]. Consequently, proactive firms are those that could obtain knowhow and experience, which develops concrete and solid innovation capability. In turn, under the resources-based theory, innovation capability helps combine and deploy firms' resources appropriately to achieve superior performance from innovative activities.

Theoretically, the above links suggest a positive relationship between proactive innovation behavior and innovative performance. Empirically, Sibanda et al. [60] studied the key factors that discriminate the performance of export companies, and found that firms that have high levels of adaptation of export marketing strategy (proactive firms) tend to have higher performance. Akhlag et al. [61] argued that proactive risk-taking strategies are the most effective innovation strategies if firms decide to heighten their performance. On the other hand, Vagnani and Volpe [62] found that a reactive innovation due to pressures stemming from the environment tends to lead to underperformance. In short, it emerges that proactive business strategies are more likely to lead to better business performance. Therefore, the following hypothesis is established:

Hypothesis 2 (H2). *Reactive innovations are inclined to be more negative towards firm performance compared to proactive innovations.*

2.2.3. Firm Constraints and the Proactive Innovation—Performance Linkage

Firms that are not constrained are those that are large and old [63]. Larger firms are bound to have greater access to the resources required for investment and the adoption of new technology. This is because larger firms have more funds available for acquiring and internalizing new technology: according to the pecking order theory, larger firms with lower levels of information asymmetry could obtain funds externally, while smaller firms have to rely more on internal funds. Coupled with the fact that innovation activities are risky due to their uncertain nature, smaller firms are likely to encounter more challenges to fund their investment in research and development activities. Besides problems related to information asymmetry, Khalifa [64] and Hall and Khan [65] pointed out that due to its operation scale, larger firms can spread the fixed costs of technological adoption over a larger quantity of units. Firms that are large are usually those that are older compared to smaller firms. With more years of operations, larger firms could be expected to become more experienced in improving their efficiency [64]. In this study, we also proxied for size by considering a dummy variable of firms with one or more than one owner. Compared to a firm with only one owner, it is very likely that firms with more owners are larger.

Besides size factor (or operation scale), firms also have constraint in their access to privileged knowledge, which can hamper their capability to innovate. In this regard, if a firm has its goods/services exported, knowledge could be exchanged between companies that are partners in the trading relationship. The flows of goods and services, as well as skilled labor, could move internationally among the partners, facilitating technological transfers. Hall and Khan [65] confirmed that as firms import highly technological products/services, they also receive knowledge and knowhow from their partners. Oum et al. [66] suggested that foreign trade has high impact for technological innovation, implying that SMEs indeed attain significant benefits from foreign counterparts, as well as from engagement in product networks, consistent with learning-by-export hypothesis.

From the above arguments, it is expected that firms with low constraints, i.e., firms that are large, have more owners and/or engage in exporting, are suitable for proactive innovation approach. This is because they could have better tangible resources (better financing options due to low information asymmetry) and intangible resources (better knowledge and experience). In turn, proactive innovation has a positive effect on a firm's capability to innovate, thus ultimately driving up corporate performance. Therefore, we suggest the following hypothesis:

Hypothesis 3 (H3). *Firms with low constraints should choose proactive innovation strategies to have better performance.*

3. Data and Methodology

Dana [67] suggested that, compared to its peer in Eastern Europe and the former Soviet Union, the reform undertaken in Vietnam has a different ultimate purpose—to allow entrepreneurship to thrive and complement state-owned enterprises, rather than completely replace them. The reform has seen huge success since its start in 1986: real income per capita adjusted for purchasing power parity in 1990 was roughly one twentieth of that in OECD, but by 2014, this ratio has surged to 13.1 per cent. To achieve even higher economic performance, Pham and Nguyen [68] opine that policies that strengthen domestic market-oriented private micro, small and medium-sized enterprises are important. These authors also argue that in the period from 2011–2015, SMEs have increased considerably in quantity but not in quality, and call for policies that support innovation activities to sustain quality growth of SMEs in Vietnam.

This study uses three rounds, collected biennially from 2011–2015, of firm-level data surveys on SME manufacturing enterprises in Vietnam. The data are a joint effort of Central Institute for Economic Management, Institute of Labour Science and Social Affairs, the Development Economics Research Group at University of Copenhagen and UNU – Wider. Each round of the survey covers firms in nine provinces of the country: Hanoi, Hai Phong, Ho Chi Minh, Phu Tho, Nghe An, Quang Nam, Khanh Hoa, Lam Dong and Long An. The sampling was based on stratified random technique to ensure that

the sample represents adequately the population of SMEs across approximately 18 sectors. The surveys provide detailed firm-level information on firm characteristics, innovation and performance. Regarding the innovation characteristics, this study focuses on technological innovation, because technological innovations are what facilitate product and process innovations. Moreover, the surveys provide reasons with respect to proactive and reactive motivations only for technological innovations. Specifically, the reasons include: "need upgrading to face competition", "upgrading was done to potentially earn profit", "everybody else is upgrading", "required by buyers to improve quality", "required by law, regulations, others". Firms' innovation strategies are categorized as "proactive" if they conduct technological innovations to improve their edge over competitors or earn higher profits (first and second motivations). Otherwise, the remaining rationales are quite reactive, i.e., following trend from competitors, the orders from regulatory bodies or customers.

In this study, conventional panel data models are compared and selected based on tests. Following the test results, it appears that firm effects are not present, thus, pooled Ordinary Least Squares (OLS) with robust standard errors was used to estimate research models. Our baseline model is as follows:

$$\text{performance}_{it} = \beta_0 + \beta_1\ \text{newtech}_{it} + \beta_2\ \text{competition}_{it} + \beta_3\ \text{export}_{it} + \beta_4\ \text{diversification}_{it} + \beta_5\ \text{age}_{it} + \beta_6\ \text{gender}_{it} + \varepsilon_{it} \quad (1)$$

We further considered whether new technological innovation that is reactive in nature has negative impact on firm performance with the below model:

$$\text{performance}_{it} = \alpha_0 + \alpha_1\ \text{reactive}_{\ it} + \alpha_2\ \text{competition}_{\ it} + \alpha_3\ \text{export}_{\ it} + \alpha_4\ \text{diversification}_{\ it} + \alpha_5\ \text{age}_{\ it} + \alpha_6\ \text{gender}_{\ it} + \mu_{it} \quad (2)$$

Finally, we added interactions of reactive technological innovation and different constraint indicators to test hypothesis H3:

$$\text{performance}_{it} = \gamma_0 + \gamma_1\ \text{constraint}_{it} \times \text{reactive}_{it} + \gamma_2\ \text{competition}_{it} + \gamma_3\ \text{export}_{it} + \gamma_4\ \text{diversification}_{it} + \gamma_5\ \text{age}_{\ it} + \gamma_6\ \text{gender}_{it} + \delta_{it} \quad (3)$$

Table 1 provides the description of the variables in the models and their respective formation as follows:

Table 1. Variable definition.

Variable	Definition	Relevant Studies
Profit_increase	Performance proxy: a dummy that is 1 if firm i's net income experiences an increase compared to that in previous year, and 0 otherwise.	Seelanatha [69], Verbeeten [70]
Sale_increase	Performance proxy: a dummy that is 1 if firm i's revenue experiences an increase compared to that in previous year, and 0 otherwise.	Capon et al. [71], Verbeeten [70]
Newtech	Receives 1 if firm i has employed new technology, 0 otherwise	Tuan et al. [46], Gunday et al. [43]
Reactive	Receives 0 if firm i deploys new technology due to its own initiatives, 1 if a firm i does this according to external stakeholders' request	Vagnani and Volpe [62]
Competition	Receives 1 if a firm i report that they feel the strong intense of competition in the market, 0 if it does not	Bloom and Van Reenen [72], Du and Chen [73]
Export	A dummy variable, receiving 1 if firms have exporting sales, 0 otherwise.	Wagner [74]
Diversification	The number of main products/services of the firm, measuring the diversification level of a firm's business.	Bhatia and Thakur [75]
Age	Age of Chief Executive Officer (CEO) of the firm	Eduardo and Poole [76]
Gender	Gender of CEO of the firm	Eduardo and Poole [76]
Constraint proxies	Large: A firm that is large is considered to have low constraint (dummy variable). Multipleown: A firm that has more than one owner is considered to have low constraint (dummy variable) Export: A firm that engages in exporting is considered to have low constraint (dummy variable)	Guariglia [63], Oum et al. [66]

Source: Author's compilation.

4. Results and Discussion

From Table 2, sale_increase is 65%, suggesting that 65% of the cases are positive, and 58% record positively increase in profit. Newtech is 0.081, meaning that only 8% of the case introducing new technology for improving process and products. Competition is 0.871, implying that 87% of the observations report that they face strong competition in the market. Reactive is 29.5%, which means 29.5% of the cases when firms introduced new technologies was due to orders or requirements from external stakeholders, rather than the own firms' willingness. 60.5% of the respondents are males, and the average age of the respondents is 46. On average, firms had barely more than 1 product. Maximum number of different goods is 8, and minimum 1. Newtech variable has 7701 observations of 0 and 1 values. When firms responded yes (value = 1) to newtech, firms also indicated the reason for their introduction of new technology. Very few firms responded to the questions of the rationales that they performed innovation, or where they sought technology.

Table 2. Descriptive statistics.

Variable	Observation	Mean	Std. Dev.	Min	Max
sale_increase	7612	0.655	0.476	0	1
profit_increase	7676	0.580	0.494	0	1
newtech	7701	0.081	0.273	0	1
reactive	623	0.295	0.457	0	1
competition	7699	0.871	0.336	0	1
export	7651	0.064	0.246	0	1
age	7700	46.109	10.860	17	94
gender	7701	0.606	0.489	0	1
diversification	7699	1.129	0.398	1	8

Source: Author's calculation.

From Table 3, the correlation matrix shows signs of correlation that are consistent with hypotheses 1 and 2. Both sale_increase and profit_increase variables are positively related to newtech, suggesting that firms may innovate to earn profits and increase sales. However, reactive is negatively related to sale_increase and profit_increase, implying that firms that innovate in response to the order or requirements of other stakeholders, i.e., regulatory requirements, demand from customers or from peer pressure, were not as successful as firms that proactively innovate.

Table 3. Correlation matrix of variables in the model.

	Sale_Increase	Profit Increase	Newtech	Reactive	Competition	Export	Age	Gender	Diversification
sale_increase	1.000								
profit_increase	0.673	1.000							
newtech	0.084	0.081	1.000						
reactive	−0.146	−0.128		1.000					
competition	−0.032	−0.018	0.048	0.025	1.000				
export	0.032	0.018	0.109	0.085	0.031	1.000			
age	−0.051	−0.060	−0.064	−0.011	−0.081	−0.075	1.000		
gender	−0.010	0.011	−0.024	0.020	0.004	−0.052	0.1702	1.000	
diversification	0.011	0.019	0.044	0.041	0.023	0.020	−0.0347	0.0041	1.000

Source: Author's calculation.

Pooled regressions showed that newtech is positively linked to profit and sale increases (significant to 1% level), which is consistent with hypothesis 1 (Table 4). This implies the beneficial effect of newtech, consistent with various studies on the process and product innovations on firm performance. Previous literature may record that different types of innovation (process and product) may come up with different success levels, but in general, innovations are positively related to firm performance. Gender has a positive effect, suggesting that male CEOs tend to be able to increase firm performance measured in terms of profit increase. Competition affects negatively corporate profitability.

Table 4. Regression result (hypothesis H1).

	Profit	**Sale**
newtech	0.141 ***	0.138 ***
	(0.019)	(0.018)
competition	−0.037 *	−0.055 ***
	(0.017)	(0.016)
export	0.02	0.042 *
	(0.023)	(0.021)
age	−0.003 ***	−0.002 ***
	(0.001)	(0.001)
gender	0.024 *	0.002
	(0.012)	(0.011)
diversification	0.019	0.008
	(0.015)	(0.014)
_cons	0.688 ***	0.772 ***
	(0.034)	(0.033)
No. of obs	7622	7559
r^2	0.011	0.011

Note: *, **, and *** indicate significance at 10%, 5% and 1% respectively. Source: Author's calculation.

Table 5 shows that the proactive innovations surpass reactive counterparts in terms of their effect on firm performance, proxied by both profit and sale increases, consistent with hypothesis H2. This result is in line with the findings in other fields like proactive exporters [60]. In a Vietnamese context, this finding presents important implications. One explanation for this could come from the planned behavior theory [60]. In the aspect of perceived behavioral control, it may be easier to tailor innovations towards firm characteristics or strategies, rather than just passively comply with regulatory requirements. Moreover, attitudes toward innovation may be more positive when firms conduct innovations to win market share, to satisfy customer demand rather than just to satisfy regulators. Regulatory requirements may not go hand in hand with firm strategy, and firms may lack control over what external stakeholders demand. Secondly, going beyond what is required may win trust from various stakeholders. Finally, when firms are proactive in innovations, they have more plans, which means that they can reserve appropriate resources. The reactive market orientation approach will always fall behind the proactive market orientation approach due to the fact that the latter address both the expressed and latent needs from customers [77].

Table 5. Regression results of reactive technological innovation (hypothesis H2).

	Profit	**Sale**
reactive	−0.129 **	−0.129 ***
	(0.041)	(0.039)
competition	−0.015	−0.01
	(0.069)	(0.060)
export	−0.029	0.002
	(0.050)	(0.045)
age	0.001	0.001
	(0.002)	(0.001)
gender	0.005	−0.073 *
	(0.037)	(0.033)
diversification	0.022	−0.021
	(0.036)	(0.036)
_cons	0.714 ***	0.838 ***
	(0.110)	(0.101)
Number of observations	621	620
r2	0.019	0.03

Note: *, **, and *** indicate significance at 10%, 5% and 1% respectively. Source: Author's calculation.

Besides rationales drawn on the planned behavior theory, based on the resources-performance linkage theory by Barney et al. [53], proactive innovation could also be expected to have a direct and positive link with firm performance [26]. Firms that have a tangible resource (proactive orientation) have a tendency to desire the status of a first mover in a competition and focus on seeking opportunities, thus, they are more likely to pool their resources for innovative activities [58]. If a firm attains first-mover status, it may face weak competition since there should be very few or even no companies that offer similar products. The resulting outcome is that the products or services of proactive firms could meet business targets. Besides the direct resources-performance linkage, there could also be an indirect resources-performance, where proactive behavior affects performance through its impact on innovation capability. The superior performance of proactive innovation is consistent with empirical studies of the proactive export adaptation by Sibanda et al. [60] and the innovation strategy by Akhlagh et al. [61] and Vagnani and Volpe [62].

In Table 5, the sole effect of reactive innovation is negative in both specifications. However, in Table 6, the coefficient of the reactive variable is only negatively significant in only one sale-related specification. This implies that the negative effect of reactive innovation dissipates when the constraint factor is considered. All the interactive variables formed by reactive variable and indicators of firm constraint (reactive_large, reactive_export and reactive_onemultiple) are negatively significant at 1% level. This result implies that, if firms that have low constraints, i.e., firms that are large, have export sales and/or have multiple owners rather than only one, should choose proactive innovation strategies to reap benefits of this strategy. Reactive innovations are prone to deliver negative impact on firm performance (Table 5), thus, for firms that have sufficient resources, the option should be proactive. This result is consistent with hypothesis H3.

Table 6. Regression results of interactive reactive technological innovation.

	Profit	**Profit**	**Profit**	**Sale**	**Sale**	**Sale**
reactive	−0.187	−0.201	−0.158	−0.131	−0.189 *	−0.121
	(0.147)	(0.139)	(0.144)	(0.111)	(0.108)	(0.112)
reactivexlarge	−0.097 **			−0.115 **		
	(0.049)			(0.046)		
reactive × export		−0.289 ***			−0.154 *	
		(0.099)			(0.091)	
reactive × multipleown			−0.090 ***			−0.086 ***
			(0.030)			(0.028)
competition	−0.005	−0.02	−0.01	0.001	−0.015	−0.006
	(0.068)	(0.068)	(0.068)	(0.061)	(0.061)	(0.060)
export	−0.024	0.071	-0.018	0.009	0.05	0.012
	(0.051)	(0.057)	(0.049)	(0.046)	(0.050)	(0.045)
age	0.001	0.001	0.000	0.001	0.002	0.001
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
gender	0.000	0.000	0.002	−0.079 **	−0.077 **	−0.076 **
	(0.037)	(0.037)	(0.037)	(0.033)	(0.033)	(0.033)
diversification	0.022	0.018	0.024	−0.02	−0.025	−0.019
	(0.037)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
_cons	0.693 ***	0.674 ***	0.712 ***	0.819 ***	0.804 ***	0.836 ***
	(0.110)	(0.110)	(0.110)	(0.102)	(0.102)	(0.101)
N	621	621	621	620	620	620

Note: *, **, and *** indicate significance at 10%, 5% and 1% respectively. Source: Author's calculation.

The results from the findings suggest that as larger firms have the more funds available for acquiring and internalizing new technology, according to the pecking order theory, larger firms with lower levels of information asymmetry can obtain funds externally, while smaller firms have to rely more on internal funds. Coupled with the fact that innovation activities are risky themselves due to their uncertain nature, smaller firms are likely to find it extremely challenging to fund their investment in research and development. Khalifa [64] and Hall and Khan [65] also pointed out larger firms can spread the fixed costs of technological adoption over a larger quantity of units due to their larger scale

of operations. We also proxied for size by considering a dummy variable of firms with one or more than one owner; the result remained consistent.

Firms also have constraints if they have limited access to privileged knowledge, which can hamper their capability to innovate. Our findings show that if a firm has their goods/services exported, knowledge could be exchanged between companies that are trading partners. The flows of goods and services, as well as skilled labor, could move internationally among the partners, facilitating technological transfers. Hall and Khan [65] confirmed that as firms import highly technological products/services, they also receive knowledge and knowhow from their partners. This result is in line with Oum et al. [66], suggesting that SMEs could derive significant benefits from foreign partners, as well as from engagement in product networks, consistent with learning-by-export hypothesis.

In summary, it is expected that firms with low constraints, i.e., firms that are large, have more owners and engage in exportation, are suitable for proactive innovation approach, because they can have better tangible resources (financing options due to low information asymmetry) and intangible resources (knowledge and experience). In turn, proactive innovation has a positive effect on firm capability to innovate, thus ultimately driving up firm performance.

Proactive behavior represents strong beliefs and great value placed on the importance of being a first mover to attain better performance [54]. Proactive orientation is the tendency to conduct innovations based on the anticipation of the market changes to grasp new opportunities [55]. Other studies such as Nasution et al. [56] and Rhee et al. [57] stated that an SME's proactive behavior could even shape the trend in the market, rather than just follow it. These huge advantages are costly in a sense that they would require significant resources to accommodate them. Large firms are able to cover these requirements with their internal resources, but SMEs and starts tend to rely on open innovations to alleviate resource constraints [78]. In conducting open innovations, several issues arise as follows.

Individualistic values can stimulate uniqueness and individualistic groups tend to be more creative than collectivistic counterparts, and this association is considered useful when creativity is a highly-valued outcome. However, individualism may bring about conflict and opportunism. Open innovation motivates individual creativeness and, consistently, open innovation decreases collectivism; in turn, individualism motivates open innovation through individual emergence. In sum, there is a positive association between individualism and open innovation, which may bring more innovative outcomes.

From macro-dynamic viewpoint, open innovation is conducive to economic growth [79,80], but this link is complicated. From a micro-dynamic point of view, open innovation should increase the complexity of target systems, and this complexity, if well controlled, could help the focal firm to obtain opportunities from evolutionary changes. Various studies have suggested that SMEs need open innovation, but the associated complexity should be controlled properly [81]. Collectivism reduces the complexity associated with open innovation [82].

One more noteworthy point is the link between serial entrepreneurs and open innovation. The former is by definition a continuous business establisher who runs a different new business after having finished another business. Serial entrepreneurs are motivated by open innovation strategies. It is interesting to note that open innovations can lead to the existence of creative and successful business models only when the associated complexity is controlled to some extent [83]. If this condition is not held, open innovation startups may collapse as a result.

5. Conclusions

In a globalization context, innovation plays a critical role in improving firm competitive edge in a sustainable manner. Proactive innovation could bring first-mover advantage, but this approach requires substantive resources. For SMEs, the decision to opt for innovation is more complex, since they suffer from higher constraints which thwart their resources and capabilities to innovate. This study uses a sample of 3504 firms in Vietnam, and aims to fill the gap whether proactive or reactive innovation

is better for SMEs, and whether proactive/reactive innovation is better for SMEs firms with higher or lower constraints.

Our findings suggest that technological innovations in general are beneficial to firm performance, as this increases firm sales and profits. We continue to dig further by filtering innovations into two categories: proactive and reactive, and examine which is better for firm performance. The result shows that reactive innovation brings negative effects to firm performance, consistent with the view that proactive entrepreneurial behavior is a highly sought-after characteristic or a valuable resource for a firm. Finally, our result indicates that if firms have sufficient resources, then proactive strategies should be the choice rather than reactive one to improve firm performance.

The findings of this research add significantly to the literature in two aspects. First, it examines the constraint—innovative performance linkage in a developing country setting. While there are a number of extant studies dealing with this link, the samples only comprise of firms in developed economies. Since SMEs in developing countries tend to experience a stronger impact of constraints, the study on the link between constraint–performance is critical in Vietnam. Second, this study found that constraints a firm faces play a role in the decision of innovation strategies, specifically the choice between proactive and reactive orientation.

Proactive innovation is beneficial towards firm performance, but it requires planning and resources and new ideas. Those factors could be obtained through open innovations, which could significantly help in the case of SMEs in developing countries due to their insufficient resources. It is suggested that individualism boosts open innovation thanks to its strong association with creativity, but the complexity from the collaboration with external parties should be controlled to some extent to ensure the stability of the business. Additionally, complexity from open innovation if well managed could be an enabler for successful serial entrepreneurs. Furthermore, open innovation should also be well handled due to its complicated nexus under the micro- and macro-dynamic viewpoints.

This research suffers from two major limitations. First, the data have some missing observations, are short and have not been updated since 2015, while innovations are the term that should be analyzed in the most current setting possible. Second, the mechanisms/factors to relieve the constraint impact on firm innovation adoption have not been studied in the current research. Therefore, future studies could seek to update the data and examine the solutions to tackle the negative impact of constraint on firm innovation.

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Open Innovation in SMEs: Potential and Realized Absorptive Capacity for Interorganizational Learning in Dyad Collaborations with Academia

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Abstract: Due to a variety of barriers to develop innovation, small and medium enterprises (SMEs) find it necessary to collaborate with external sources of knowledge. The current study analyses the collaboration between SMEs and academia over an open innovation setting in Mexico. An absorptive capacity (ACAP) approach has been applied to understanding the process of developing new knowledge for achieving innovation. A two-part questionnaire was developed with the aim of assessing the ACAP of a new joint research unit. Data was collected from a local group of SMEs that collaborated as dyads with academia supported by a government program of innovation in Mexico. The result shows that there was a moderate potential and realized ACAP in the sample; these results are mutually related with both parts of the questionnaire which supports our findings. In conclusion, exploitation of new knowledge is a complex dimension for creating value from collaboration, which makes the outcome difficult to measure using traditional means. It can be argued that exploiting new knowledge for innovation is an iterative process of learning when exploring new sources of knowledge from academia.

Keywords: open innovation; absorptive capacity; collaboration; joint research unit; exploitation; SMEs

1. Introduction

In the new global economy, innovation has become a central issue for economic growth and success for firms. Important findings have provided enough evidence to show that innovation is a key factor in the new knowledge economy. Knowledge creation has become the basis of innovations, and an innovative organization is capable of creating new knowledge [1]. A growing interest of exploration for new sources of knowledge for innovation is removing the barriers to collaboration, providing therefore, an alternative way to the traditional closed perspective of research and development (R&D). Although there are several studies related to collaboration among large companies and open innovation (OI), there is still a lack of research focused on small and medium enterprises (SMEs) [2] under an absorptive capacity (ACAP) approach [3] and from a joint research unit perspective.

Since the theoretical development of open innovation, various cases have been studied [4] in different institutional settings of actors in networks of innovation systems (i.e., the "triple helix") [5], in order to address innovation as a multi-actor complex phenomenon. The turbulence of the business markets has ensured focused attention on knowledge as a dominant source of innovation and competitive advantage. Firms find it necessary to recognize new external knowledge, assimilate it, and apply it to commercial ends, also known as absorptive capacity [6]. ACAP is viewed as both an intra- and inter-organizational learning process [7], where the principal role is achieving innovation [8], and SMEs are particularly transitioning from the traditional perspective to include more creativity and innovation-based measures [9].

From a resource-based view of the firm [10], SMEs, in general, have limitations regarding achieving innovation [11]. Therefore, there is a need for a change of perspective, which involves opening and looking for external sources of knowledge for a collaborative learning environment. In this sense, governments have been working on policies to encourage innovation among SMEs. The necessity of working in open collaborative settings is becoming a benefit, and at the same time, a challenge. Because of this, SMEs may be hesitant to risk their current state, due to the experimental nature and the needs of extensive resources for research that become obstacles to undertake innovation by themselves; support from other actors is required to reduce the risk of failure.

For these reasons, our study focuses on dyad collaborations supported by the government in Mexico, at the unit level, where the exchange of knowledge between SMEs' workers and researchers from academia is executed. According to Cohen and Levinthal [6], ACAP not only resides in firms but also in organizational units. Therefore, establishing successful external collaborations in a joint research unit is a key aspect to developing capacities to create and disseminate new knowledge across the organization, which could result in superior performance by the firm. For this purpose, we aim to understand the ACAP generated by collaborative work between SMEs and academia to assess the potential and realized capacity of developing new knowledge for innovation at the unit level. Our study responds to the research gap in the understanding of ACAP from an interorganizational collaboration setting by studying a new joint research unit created in the SMEs that collaborate as dyads with academia in a developing country such as Mexico.

The article proceeds as follows. First, the implications of open innovation and SMES are drawn to develop a contextual base for the study, allowing for the construction of our theoretical base of ACAP and its components. Second, we present analysis of the results of our data, which was collected using a two-part questionnaire given to a group of SMEs in Mexico. Finally, we discuss the findings and draw appropriate conclusions.

2. Open Innovation and SMES

Open innovation (OI) emphasizes that the abundant external knowledge can be converted into innovation. Henry Chesbrough [4] coined the term "open innovation," which combines internal and external knowledge for the creation and commercialization of new products and services. Contrary to the closed perspective, open innovation claims there are benefits to the accelerating use of new knowledge. The main argument of the dichotomy of open and closed innovation resides in the R&D being executed as an internal (closed) key competitive advantage, whereas the open R&D focuses on finding new knowledge from outside that can be used collaboratively for the development of innovation. After many years of development of the concept, Chesbrough and Bogers [12] redefined the concept of OI as a distributed innovation process based on the management of knowledge flows through organizational boundaries. Although the concept is focused primarily at the firm level, there is the notion that OI can work at various levels across the organization, where boundaries become more open as the permeation increases to other levels (i.e., units inside the organization) [13]. Open innovation practices provide an alternative strategy for SMEs to access new external resources of knowledge at a low cost, minimizing obstacles, such as financial, technological, and human resources, that obstruct a growth-oriented perspective to access new markets. The OI model states that enterprises can acquire external knowledge from different market-based partners like customers, suppliers, competitors, and science partners from universities or research centers [14,15], therefore establishing an integrative knowledge capability through practice to support the development of the overall innovative capacity.

Nevertheless, SMEs still preserve a closed perspective to innovation, relying mostly on internal sources of knowledge to develop new products and services [15], where innovation efforts mainly aim to keep up to date with the markets [16]. The non-existence of R&D activities, due to the high costs involved, are also a determinant of the innovativeness levels of SMEs. Cooperation with other firms, suppliers, and customers have a more prominent role in the innovation process of SMEs than cooperation with research centers, universities, and government institutions [17]. The ability to

collaborate with other science-based institutions allows SMEs, with less financial and human resources, to not only develop new knowledge for new products or services, but also to introduce changes into their production processes, as well as to improve the management of the organization's resources. Nevertheless, a willingness to share valuable information from the SME needs to be done for these types of collaborative open settings. In contrast, larger firms are more familiar with collaborative relationships with external partners, such as suppliers, customers, or universities, and sometimes with competitors, to gain value from the co-creation processes [18]. Specifically, collaboration with universities or research centers increases the SMEs' internal knowledge and fosters innovation [19]. Furthermore, it has been found that small companies could compete with large companies when they consider more types of innovations [20].

In terms of open innovation settings, despite the constraints and barriers of resources to execute R&D internally, SMEs can gain more benefits undertaking open innovation than large firms as they can be more flexible, which also provides a motivation to look beyond their organizational boundaries [2]. Some barriers to open innovation in SMEs are related to cultural and organizational issues that appear when they start to interact and collaborate with external partners [16]. Cultural issues are mostly found in SMEs, principally family businesses where owners/managers usually have more operational expertise; therefore, the perception of managers' task on the competitive environment plays a significant role that facilitates the organizational learning activities in SMEs [21], but SME managers often lack some resources, especially time, to undertake innovation [22].

Isolation oriented toward the interior of the organization with limited links or channels of information is one of the main reasons for companies producing less innovation [23]. However, internal actors play a fundamental role in recognizing the opportunities of the market through the development of internal technological capabilities complemented with external assistance [24]. Internal and external resources are key determinants for the innovation of SMEs, but the connections among resources are determined by the owner/manager capacities, therefore, the manager's expertise can determine the innovativeness of the firm [25]. A lack of manager training regarding new technological competencies also becomes a barrier for innovation; having the proper knowledge has been linked with the innovativeness of the firm [26].

Investing in innovation also requires a great extent of risk inclination, even in larger companies. Risk predisposition can make a difference in innovation; executing internal research can be difficult due to the resource constraints in SMEs [27]. The managers of SMEs are mostly conservative and averse to taking risks [28,29], which results in lower innovativeness. Lack of financial capacity also provides a difficulty toward capitalizing spotted opportunities in the market due the high risk and cost involved with R&D [30].

Governments are favoring collaborations with programs and policies more often to encourage and increase new knowledge creation and competitiveness of firms [31]. While investment in SMEs with financial support resolves one of the barriers, specialized knowledge is still needed as a complementary resource. On the other hand, academia has specialized expertise interested in the practical applications of their research; therefore, an inter-organizational learning setting is established. In this sense, both actors provide the synergy required for the beneficial outcomes from a joint research project. Although this is an expected consequence, the process of developing innovation is not straight forward as both sides might have different approaches toward addressing a phenomenon, which could result in discrepancies during the exchange of knowledge and thus, influencing the outcome of the project. Although the emphasis of governments is placed in terms of the amount invested and the expected results as traditional measures of innovation (i.e., patents), it neglects in some way the complex process that exists in collaborations and other indirect factors that are difficult to measure. The concern of the appropriability of innovation via patents is still debated among scholars; from one side, it is likely to enhance the private economic returns to the disadvantage of the social returns of innovation, and from the other side, it limits research on incremental innovations and therefore the creation of new spillovers. In some cases, patents are better for large firms and very difficult for small businesses [2].

Another factor for innovation in SMEs could be the geographical location since it has been found that there is a strong connection between the concentration of SMEs and public research in local places [32]. Firms with greater resources devoted to R&D (i.e., large firms) tend to rely more often on spillovers from distant institutions than firms with fewer resources in R&D (i.e., SMEs) [33]. Approaching local universities or research centers helps to provide an advantage for SMEs in this sense due to the difficulty of having an in-house R&D. The geographical proximity between firms and universities is of significance for benefits, such as direct assistance in problem solving, since it facilitates the exchange of tacit and context-specific knowledge [34]. This exchange is due to the proximity to resources (human resources and capital) and science-based institutions that underpin networks, which promotes innovation [35].

3. Absorptive Capacity

Knowledge is assumed to be useful in the sense that increasing a firm's knowledge will increase its performance; it is among the most valuable resources. The need for acquiring new knowledge from different sources is part of every organization, and ACAP theory is focused primarily on the process of absorbing new knowledge. Cohen and Levinthal [6] conceptualize ACAP as the ability of the firm to recognize the value of new external knowledge, assimilate it, and apply it to commercial ends. According to the knowledge-based view theory [36], ACAP is viewed as an enterprise's attitude toward recognizing and perceiving not simply the knowledge from outside that can be helpful to create value, but also as the capacity to assimilate and integrate the knowledge to make it usable for the creation of innovation [37].

ACAP starts from firms searching and identifying a need for new knowledge from outside the organization to cope with a growing turbulent market and builds upon previous developmental investments of individual and organizational absorptive capacities; therefore, ACAP will tend to develop cumulatively. An organization's ACAP is not resident in a single individual but depends on the links of a variety of individual capabilities [10,38]. A diversity of knowledge sources suggests a broader perspective. Thus, firms with higher levels of ACAP will manage external knowledge flows more efficiently, stimulating innovative outcomes and thus obtaining competitive advantages [39]. ACAP enablers, such as internal R&D, external R&D, and employee expertise, have a positive influence on product innovation [40]. Nevertheless, there are abundant studies of ACAP under a variety of explanations—for example, as a process of exploratory, transformative, and exploitative learning [41]—as additional dimensions of ACAP, such as the recognition of value from new external knowledge as a previous step of acquisition [42], albeit most attention has been concentrated on tangible outcomes [43].

Zahra and Georges' [44] reconceptualization has been widely accepted and tested in different industries and contexts. The main argument suggests a two-phase model of ACAP: a potential absorptive capacity (PACAP) that includes acquisition and assimilation of knowledge capabilities, and realized absorptive capacity (RACAP) that includes transformation and exploitation of knowledge capabilities. Both phases are complementary to drive performance outcomes, such as competitive advantage and innovation. The main argument of the ACAP model is that PACAP precedes and influences RACAP, and every phase of the model provides a base for a systematic understanding of ACAP. The breadth of knowledge that a firm acquires and assimilates will determine how far its exploratory learning from the current knowledge can go and how it can be exploited for the organization's benefit.

Potential Absorptive Capacity and Realized Absorptive Capacity

The first phase of the model (PACAP) considers the two capabilities of acquisition and assimilation. Acquisition refers to the firm's capability to identify and acquire valuable external knowledge. However, as Cohen and Levinthal [6] states, it is simply insufficient to expose an individual briefly to the relevant prior knowledge; therefore, it is difficult to recognize an organization's need for specific knowledge if

no prior research has been undertaken previously. Hence, acquisition does not relate purely to the external sources, but also to the research experience acquired. Studies reveal that previous experience with knowledge searches is a significant antecedent of PACAP, and as such, has implications for the ACAP accumulation process. [45]. The intensity and speed of the efforts to identify and gather knowledge also determine the quality of the acquisition capabilities of the firm [44], meaning that firms with more developed internal research capabilities could benefit more from collaborations [46]; this goes in line with the view of the identification and evaluation process of external knowledge suggested by Cohen and Levinthal [6].

Assimilation, on the other hand, are routines and processes that permit a company analyze, interpret, and understand knowledge obtained from external sources. Interpretation of external knowledge is also related to prior knowledge acquisition [44]. A firm's ability to learn from another firm through dyads depends on the firms' knowledge similarity bases, organizational structures, and compensation policies [7], where the internalizing of knowledge is better when they have similar knowledge-processing systems. Therefore, to increase the innovative performance of companies, it is recommended to target other partners with moderately related knowledge bases [47]. Comprehension represents the knowledge articulation of the collaboration, which is the degree of acquisition of new knowledge from the counterpart. The similarity in researching processes should also be connected to the project to achieve an effective understanding of the external knowledge [7]. Therefore, practical work during the execution of the project represents mutual learning, which is achieved as the project advances and unplanned issues start to appear. Learning from experience through repetition suggests the accumulation of incremental improvements and progressively results in better ways of doing things. Excessively ambitious plans could be replaced by more realistic ones, and unnoticed opportunities could be exploited in the next period [48]. Changes and eventual needs for more resources will appear during the execution of the project, where possible loops and iterative processes might exist to move to the next phase of the model. From the individual level, they represent important sources of organizational knowledge as agents of learning, with the ability to transfer tacit and explicit knowledge, and to adapt their knowledge to new contexts [49].

The second phase in the model consider the two capabilities of transformation and exploitation. Transformation is the capability to develop and improve the routines that facilitate the combination of the existing knowledge with the acquired and assimilated new knowledge [44], which is a bisociation of the old and new knowledge, leading to a modification and conversion of current routines with the experience and practice obtained in executing the project. Bisociation is the process of combining matrices of information that allows the identification of an opportunity and seizing it through action [50]. Therefore, expertise integration is a procedure by which individually held knowledge is applied to the project [51]. In collaborative settings, bisociation exists, first with the combination of existing and old knowledge, and second, with the specialized new knowledge brought by the external organization. Thus, a modification within the existing competencies and reinterpretation of knowledge is carried out, leading to the development of new useful knowledge for the project unit and then to the firm. In this sense, intrafirm knowledge dissemination is supposed to increase responsiveness to the environment if SMEs have well-developed capabilities in external knowledge acquisition [52]; consequently, transforming and exploiting knowledge requires a well-connected knowledge structure between intraorganizational members [47].

Exploitation is the last component of ACAP. As Cohen and Levinthal [6] state, ACAP refers not only to the acquisition or assimilation of knowledge by an organization, but also to the organization's capability to exploit it for commercial ends. The outcomes of systematic exploitation routines are the continual creation of new products and processes or new organizational forms [53]. Nevertheless, firms may be able to exploit knowledge serendipitously, without specific systematic routines, which reflects the ability to harvest and incorporate knowledge in their operations [44]. Although it is possible to consider exploitation as an output of ACAP, a reconsideration of the early development approach of ACAP is needed, where commercialization of knowledge was stressed as a traditional way of measuring

the results of R&D investments. Exploitation is also evident, for example, in new ventures that capture knowledge from outside of the boundaries, which is used to generate new competencies [44]. Hence, it is worth considering both sides as outputs—commercial (products, services, and patents) and knowledge use (scientific, technical, operational and organizational)—on the absorptive capacity research, where firm performance is influenced by both types of absorptive capacity outputs [41]. Successful joint research would ultimately lead to obtaining both outputs, although benefiting the organization to different extents. The complementarity of both PACAP and RACAP will yield superior performance, while the ability of exploitation will represent a competitive advantage that will lead to innovation. Nonetheless, it is necessary to balance both phases, as argued similarly by March [54] regarding exploration and exploitation, where organizations need to manage a balance between exploratory and exploitative learning.

4. Research Design

The phenomenon of open innovation has been studied in different types of firms and industries [55]; however, our study focuses on the new joint research unit that collaboratively executes the project of innovation in open settings as dyads between SMEs and academia. We emphasize the integration of knowledge of an interorganizational collaboration to assess the ACAP that is emergent from the new joint research unit. Different from a whole organizational ACAP, the results from a unit could eventually lead to the dissemination of knowledge to the whole organization. Our interest, therefore, aims to find the development process of new knowledge through a dyad collaboration and the subsequent use of the outcome for innovative purposes.

Investing in R&D means an extra effort for the SMEs; it represents a degree of risk inclination since exploring unknown sources is time-consuming and requires an investment of many resources. Although SMEs usually focus their attention on the exploitation of their current technology and products, it is significant for them to keep running their systems to keep producing and attending to their market; for these reasons, a new joint research unit is required. It has been found that a sole unit can be more innovative than a large multiunit company if they have absorptive capacities and access to the central internal network [8]. In this sense, the support obtained from the government will let the SME overcome financial barriers to undertaking research. It also gives them the possibility of using external specialized knowledge support from academia to execute a joint research project for innovation. There is evidence that adding newly qualified people to the firm will increase the absorptive capabilities [2]. Thus, the incorporation of experts from academia could lead to a better performance in terms of innovation in SMEs.

5. Methodology

For our objective, we used a set of items based on Zahra and George's [44] construct and other additional support studies with the aim of understanding the absorptive capacities generated in the collaborative research carried out by SMEs. Our main assumption rests on the incorporation of researchers from academia into SMEs that could lead to obtaining a higher degree of absorptive capacities in the joint research unit and will generate a valuable outcome from the collaboration.

Based on the theoretical construct, we developed two sets of questionnaires for an explorative research as a first approach to the process of knowledge creation and to find possible outcomes from the execution of the project. Project leaders of the new unit are the target participants in this sense as they appropriate information from the experience that will allow us to understand the ACAP in the new joint research unit.

The study is exploratory as we first gathered information in the form of multiple-choice questionnaire to further complement the data with correlational analysis in the second part. The questions were tested for general understanding and also to find possible errors. The results are specific to the context of the group of firms, and its main purpose was to give insights about the practice of collaboration in SMEs from experience under an ACAP approach. A total of nine

items were designed based principally on Zahra and George's model [44] as an inter-organizational process. The scope of every item is shown in Table 1. The first part of the survey consisted of a set of multiple-choice questions based on the theoretical variables previously addressed, with the objective of complementing the second part of the questionnaire. The second part consisted of questions answered using a five-point Likert scale (1–5) to understand the interconnectedness and to run a correlation analysis of the variables. The aim of the two parts of the questionnaire was to obtain richer information and offer a convergent explanation.

Table 1. Operationalization of the variables, items, objectives, and references.

Phase *	Variable *	Items	The Objective of the Questions	Supporting References
Potential Absorptive Capacity (PACAP)	Acquisition (X1)	Item 1	Previous experience with research	Fosfuri and Tribó [45]
		Item 2	Intensity, speed of acquisition, and exchange of knowledge	Zahra and George [44]
		Item 3	Comprehension and understanding of external knowledge	Lane and Lubatkin [7]
	Assimilation (X2)	Item 4	Learning	Maskell and Malmberg [48]
		Item 5	Application of knowledge in daily work, new ideas	Easterby-Smith et al. [49]
Realized Absorptive Capacity (RACAP)	Transformation (X3)	Item 6	Bisociation	Smith and Gregorio [50], Zahra and George [44]
		Item 7	Modification (conversion)	Tiwana and Mclean [51]
	Exploitation (X4)	Item 8	Implementation	Zahra and George [44], Lane, Koka and Pathak [41]
		Item 9	Use of knowledge for commercial purposes	Cohen and Levinthal [6]; Lane, Koka, and Pathak [41]

* Variables based from the theoretical construct of Zahra and George [44].

6. Sample

Our sample consisted of a group of SMEs in Mexico City that worked in a joint research project of innovation supported by a government program that lasted for one year. We used a public database to find a total of 16 participating SMEs that collaborated with academia. Among different projects from diverse companies, the government institution decided according to their parameters and budget which projects are the subject of interest for their objectives and which should be funded. Therefore, the number of participating SMEs was small as only a few fulfilled the requirements. The participating SMEs were heterogeneous, ranging from services to manufacturing. We focused on a local area since a geographical proximity between the firm and its university partners have been found to be of significance as it facilitates the exchange of tacit and context-specific knowledge [34]. Two main characteristics of the SMEs were important for the study: participation in the funding program with projects to develop innovation and having collaborated with a research center or university. Among the 16 SMEs that received the funding according to the database, three never replied to the answers of the questionnaire and three SMEs were not found to be able to contact. Therefore, a total of 10 valid responses were collected using telephone calls and questionnaires sent by email. The study was developed independently of the participating SMEs, academia, or the government in order to avoid biased information and to encourage participation of the group of SMEs. We informed and stressed to the participants that the collected information was anonymous and confidential information was not required about the specific research project but instead information about the experience of the process of collaborating with academia in which they agreed to participate.

The items of the scale were tested using the Cronbach's alpha for the reliability value, which must be equal to or greater than 0.7 [56]; a coefficient of ($\alpha = 0.73$) was obtained, which as an exploratory study, is enough for the purpose of the present study.

7. Data Results

The first part of the questionnaire aimed to bring new insights as a first approach to the phenomenon. Every subset of the variables was related to the items previously mentioned; therefore, nominal data was obtained in a set of closed-answer questions to further ponder the data and obtain descriptive statistics for a statistical analysis. The second part of the questionnaire consisted of Likert scale questions to obtain ordinal data for an alternative analysis. The number of participants in the target group was ten (N = 10), and although the number of SMEs with the specific characteristics was small, a correlation analysis was enough to give complementary information and a further convergent explanation.

For the first part of the questionnaire, every item was designed according to the theoretical construct. A set of closed questions with possible answers for an easy understanding was developed such that technical words were avoided. Every item was rated on a scale of 4 to 1, which was assessed according to our theoretical construct. The first degree of the response shows the high (4), optimum or desired answer, meaning that an optimum capability was found on the item. The second degree was labelled as good (3), meaning a medium or minimum degree of the capability; the third degree was labelled as enough (2); and the fourth degree, the least desired answer, suggested a low amount or absence of the capability (1). The questionnaire also had the option of not answering any of the statements if not agreeing with the question. Table 2 shows the results with descriptive statistics and the frequency of responses separated by the degrees just mentioned.

Table 2. Descriptive statistics and grouped frequency of answers separated by degree of ACAP (N = 10).

		Mean	SD		High (4)	Good (3)	Enough (2)	Low (1)	N/A *
PACAP	Acquisition	3.25	0.42	Item 1	5	5	0	0	0
				Item 2	4	4	1	1	0
	Assimilation	3.3	1.02	Item 3	8	0	1	1	0
				Item 4	7	2	1	0	0
				Item 5	4	3	2	1	0
RACAP	Transformation	3.3	0.75	Item 6	7	3	0	0	0
				Item 7	3	5	1	1	0
	Exploitation	2.55	0.49	Item 8	3	1	6	0	0
				Item 9	1	1	8	0	0

* No answer.

From the first part of the questionnaire of our group of SMEs (N = 10), we assessed the nominal answers by degrees from 4 (highest) to 1 (lowest) for a descriptive analysis. The first variable of "acquisition" averaged 3.25 (SD = 0.42), the second variable "assimilation" averaged 3.3 (SD = 1.02), the third variable "transformation" averaged 3.3 (SD = 0.75), and the fourth variable "exploitation" averaged 2.55 (SD = 0.49). The descriptive statistics showed on average a good to high capability for the first three variables, but the fourth variable showed an enough or low capability for exploitation. On the other hand, the frequency of the answers of every item in the PACAP dimension regarding item 1, showed that most respondents stated they had previous experience in research for innovation in products or processes (a majority concentrated in high = 50% and good = 50%). The intensity, velocity, and acquisition of knowledge regarding item 2 showed a high and enough ACAP, meaning that there was a good intensity of shared information for the execution of the project (a majority in high = 40% and good = 40%). Assimilation capacity regarding item 3 showed a good articulation of the knowledge,

observing a majority with high ACAP (high = 80%). Regarding item 4, a majority was situated in high ACAP, observing a high degree of learning across the progress of the project (high = 70%). Item 5 referred to the utilized knowledge for daily work, which showed a high and good ACAP, meaning an ability to find and use new solutions for the products and processes (high = 40%, good = 30%). For the RACAP dimension, item 6 showed that there was a good bisociation of knowledge (high = 70%). Item 7 showed a good modification of the previous knowledge to be implemented inside the organization (high = 30%, good = 50%). The exploitation variable on the other hand showed most respondents had an enough degree of ACAP regarding item 8, which showed that the knowledge developed was not applied completely to the existent competences for most respondents. The knowledge output was principally stored in the internal database (a majority in enough = 60%). Item 9 showed that most respondents had an enough degree, stating a need for more research, time, and investment to achieve commercialization (a majority in enough = 80%).

The second part of the questionnaire consisted of a set of ordinal Likert type scale from 1–5. Data were grouped from X1–X4 for every variable with the purpose to run a correlation analysis from the theoretical construct of ACAP. A Spearman's ρ (rho) bivariate correlation was executed for the data analysis using statistical software. The results are shown in Table 3, where X represent each variable of absorptive capacity.

Table 3. Bivariate correlation analysis.

Method	Variables		X1	X2	X3	X4
Spearman's ρ	**X1**	Correlation Coefficient	1.000	0.641 *	0.867 **	0.317
		Sig. (two-tailed)		0.046	0.001	0.372
		N	10	10	10	10
	X2	Correlation Coefficient	0.641 *	1.000	0.834 **	−0.111
		Sig. (two-tailed)	0.046		0.003	0.761
		N	10	10	10	10
	X3	Correlation Coefficient	0.867 **	0.834 **	1.000	0.237
		Sig. (two-tailed)	0.001	0.003		0.509
		N	10	10	10	10
	X4	Correlation Coefficient	0.317	−0.111	0.237	1.000
		Sig. (two-tailed)	0.372	0.761	0.509	
		N	10	10	10	10

* Correlation was significant at the 0.05 level (two-tailed). ** Correlation was significant at the 0.01 level (two-tailed).

Table 3 shows first that acquisition (X1) was positively and significantly correlated with assimilation (X2) (0.641, $p = 0.046$), therefore having congruence to engage the potential absorptive capacity of the model. Assimilation (X2) was also correlated significantly with transformation (X3) (0.834, $p = 0.003$). In the same line, X1 was correlated with X3 (0.867, $p = 0.001$), giving congruence with the first part of realized absorptive capacity. Interestingly enough, no significant correlation between transformation (X3) and exploitation (X4) was found (0.237, $p = 0.509$), and with none of the rest of the variables. Since the purpose of this paper was not testing the model in successful collaborations but exploring the emergent absorptive capacities of the new joint research unit, we found that there is a partial ACAP in our sample, showing that a good correlation of the three first variables could not lead to achieving exploitation in this particular group of SMEs. To provide a possible description, we will use both parts of the questionnaire as a convergent way to explain the results without the objective of generalization of the phenomena.

8. Discussion

Both parts of the questionnaire complement our findings. As we aimed from the beginning, this assessment of ACAP in the group of SMES did not intend to test the model for validation, but instead to understand the ACAP generated by the joint research unit inside the SME. The new unit

was, to some extent, experimental as normal operations must continue working as the project was executed. There was no obligation to show tangible outcomes or commercialization success. Therefore, no innovation aggregate was possible for measurement through traditional means when the general assumption of innovation stresses the commercial success on the market to call it an "innovation" [57]. A simplistic view of innovation in SMEs is still frequent among policymakers who see them as nascent large firms that have to exploit innovation to achieve their growth potential [22]. Nonetheless, ACAP literature shows the importance of exploitation, not only by commercialization, but also by the creation of new competencies as knowledge outputs. This can be more adequate for understanding the process of developing innovation and thus it might suggest new indicators for innovation measurements, especially for SMEs.

SMEs might need to adapt and acquire enough capabilities to successfully exploit new knowledge; therefore, a continual iterative process of learning might occur when they collaborate with academia. The difficulty of measuring subjective achievements is their imprecision as there are no tangible results during the first phases of the development of innovation. An issue that could explain a difficulty for achieving exploitation is the risk of projects not being continuously funded or with irrelevant objectives when carrying out research. For example, a problematic continuation of support from research centers was found to be discontinued as the funding ended in collaboration settings [58].

From our results, we can show that the studied group of SMEs units collaborating with academia in the specific local context studied showed a moderate ACAP. The process of obtaining tangible outcomes from commercializing the results of the research as exploitation is still a concern for the group of SMEs. Interestingly, most respondents have shown a degree of transformation of their routines or processes as a result of the project, but not as an exploitation of the knowledge created. This shows an indirect improvement for the organization as a consequence of the collaboration, where an extent of knowledge permeation was observed that went from the unit to the rest of the organization as part of the dissemination process. Our findings also brought insights about the new emerging unit in terms of ACAP, which might gradually improve over time to bring results as strategic resources to the organization (i.e., new ventures, spillovers, patents, products, and services).

Open innovation is intended to accelerate the process of innovation. Nevertheless, accelerating the process seems to be a challenge for SMEs as they respond to a small portion of the market with different barriers and limitations, but undertaking OI represents an iterative way of learning for continual growth. Their increasing know-how will constitute valuable and indispensable knowledge to run their processes, which can be exploited over the long-term. For that reason, intellectual property is a concern among SMEs, especially in developing countries where the traditional family business is often closed to outside intervention. An interesting motivation for research could grow from new generations of SME owners that encourage an open approach to address innovation as new business models.

9. Conclusions

We analyzed the results of an open innovation collaboration between SMEs and academia under an absorptive capacity approach. The principal objective was to understand knowledge creation in collaborative projects. Theory and growing interest in research of open innovation show the possibility of achieving innovation in different ways other than the traditional view of closed R&D. Hence, internal R&D is not merely a proxy for ACAP, but rather a base to create complementary assets and capabilities with external partners that will enable opportunities for future knowledge acquisitions [59]. ACAP, in this sense, was appropriate to address the creation of new knowledge collaboratively.

The government institution decided which SMEs would participate in the program for their projects of innovation, and for that reason, our sample was heterogeneous and limited the studied context. Certain attributes were not reflected in the results as the information was not available. This included types of innovations, age of the entrepreneur, sector of the firms, and other attributes. Nonetheless, the predisposition to work collaboratively is evident for SMEs, despite its characteristics.

Greater efforts and attention are needed since knowledge exploitation depends on repeated and intense interactions with diverse actors.

From the data collected, our findings showed some patterns among the SMEs joint research units in terms of ACAP. This was supported by the results of both parts of the questionnaire that provided a convergent explanation of the observed phenomena. ACAP refers to the organization's ability to exploit knowledge to provide commercial outputs. As shown from our results, the knowledge created by the group of SMEs was not totally unproductive. It is possible to observe an indirect way of learning, where the main output observed from the collaboration was found in internal improvements. This might turn into continual learning, where the benefit from participation on this type of programs have provided experience to the SMEs that could effectively exploit this knowledge in the future. Nevertheless, it will require significant efforts from the whole organization to accomplish this situation (i.e., absorptive capacity is not a by-product). Although it is observed that ACAP enablers are the internal and external R&D undertaken for the generation of product innovation [40], our study showed in our sample of SMEs that as a consequence of collaborative R&D, exploitation was an iterative process of continual learning when exploring new sources of knowledge from academia. However, as long as internal and external R&D continue developing in conjunction, a benefit from commercialization could be achieved in the future. This goes in line with the assumption that the external knowledge processed through PACAP must go through various repeated cycles before the organization can apply it commercially through RACAP and generate business value [16].

We argue that time taken for a joint research is related to the experience obtained when working in open settings. Future specialization and familiarity with joint research processes are a primary concern during the first stages when working with academia. This, in turn, might translate into reducing the time of exploitation of the created knowledge for internal and commercial benefits in the future, but time is a difficult variable to address. Open innovation stresses that time for developments are shorter under this approach, suggesting that organizations must focus on exploiting new knowledge instead of searching for the intellectual property of the knowledge. SMEs might also need a change of their traditional business view, where the emphasis should be placed mainly on exploiting their principal products over long periods to provide a greater diversification and a continual improvement of their products. This, in turn, will lead to the development of new dynamic capabilities that are necessary to cope with the turbulent markets. A change of perspective could also be turned into the growth of small and medium enterprises that are gradually opening to innovation.

Besides funding, more support is also needed from governments, which could work as moderating variables in the process of developing innovation. It is expected that in future collaborative innovation projects, SMEs could obtain better outcomes with academia if new measurements and guidelines are developed. The participation of other relevant actors in adapted systems of innovation could also suggest the creation of a useful network of dyads defined according to the strategic needs of the organization. Therefore, SMEs should not only rely on one source but on a network of sources. However, the complexity will increase for managing multiple connections. A need for mutual trust with other participants in open systems of innovation is essential; therefore, prior preparation and experience in collaborative research is necessary to achieve beneficial outcomes from such networks. The dyad collaborations between SMEs and academia in this study denoted a first step of learning for them as a continual process of exploring for new sources of knowledge.

It can be recommended that researchers and business managers should initiate and participate in the co-production of knowledge as a collective effort in SMEs. The investment of more time and attention needs to be encouraged to consolidate a successful collaboration. These findings also bring new observations for future research in the field of exploitation of knowledge for innovation in alternative ways, which could possibly bring insights regarding new measurements and guidelines for innovation tailored to the characteristics of SMEs.

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Innovation Strategy in Small and Medium Sized Enterprises (SMEs) in the Context of Growth and Recession Indicators

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Abstract: The implementation of innovation strategies in SMEs is subjected to changes in the economic cycle. The reliability of economic trend indicators varies according to economic trends. The author deals with the relationship between selected business cycle survey indicators and time periods that correspond to the different phases of the economic cycle between the years 2003–2017. The aim of the article is to find out whether selected business cycle surveys indicators are equally reliable across the economic cycle. To solve the problem, first, the consensus of a selected business cycle surveys indicator and the performance of the mechanical engineering industry were evaluated, and then, the results were put into the context of the time period and tested with nonparametric ANOVA. The results show that the selected indicator was more reliable in periods of growth and less reliable in downturns, which is a signal for SMEs as to how to interpret the business cycle surveys. The use of future development assessments provides important information for businesses that make investment decisions and help them think over funding for innovation.

Keywords: innovation; business cycle surveys; economic cycle; SMEs

1. Introduction

Does the reliability of business cycle prediction change in relation to the phase of the economic cycle? Is it possible for companies to rely on such predictions? Economic fluctuations have a significant impact on how companies act in the markets, and whether they are able to innovate to build their competitive advantage. Their expectations vary at different stages of the economic cycle.

The SMEs are also under the strong influence of the business cycle. Everett and Watson [1] point out that 30–50% of small business failure is associated with economic factors. Bhattacharjee et al. [2] state that at any business cycle phase, every business faces the threat of bankruptcy or acquisition.

Both expansion and recession may signify an opportunity to grow for both individual businesses and industrial policy at the macro-level. Many authors [3–6] studied how businesses change their innovation behavior during business cycles. Innovation during a recession affects a company's success in the recovery period [7–9], and delaying innovation action could be costly in economic terms [10].

The economic cycle, characterized by macroeconomic variables, affects companies' profitability and potential corporate failures [2]. Economic indicators help to deepen understanding of diverse economic behavior [11] and making more accurate decision making [12].

Precise and reliable estimates are crucial for business decisions [13]. The well-estimated development of the economic environment helps companies to adapt and to avoid unnecessary losses and thus help their sustainable development. The more uncertainty in the business cycle expectations, the more negative impacts on the economic activity of a company persist [13]. Therefore, the more innovative ones learn how to exploit the business cycle indicators.

The article investigates whether small and medium-sized businesses can rely on the predictive capabilities of selected business cycle survey indicators more during times of economic boom or during a recession.

The business cycle surveys (BCS) are the basis for estimating the expected economic development [14,15]. This data is well accessible across the member countries of The Organisation for Economic Co-operation and Development (OECD). Its advantage is that it is not revised and does not contain errors [16,17]. BCS enter into composite leading indicators which are the tools for discovering future economic development. Generally, the demand for short-time macroeconomic analyses is growing [17].

The method of the evaluation of the leading indicators proposed by the article is conceived being a complement to econometric studies with the aim of bringing the issue closer to the application sphere. It employs the indicators, which were not modified, and it is clear how they were created. Moreover, the predictions can be traced back to their beginnings [18].

The research showed that the business cycle survey indicators were more reliable at a time of economic growth, but their predictive ability decreases at the time of economic downturn.

The following text is arranged as follows. Firstly, the literature review is introduced in Section 2, then, in Section 3, the materials and methods are explained. In Section 4 the results are described and Section 5 presents the discussion. Finally, Section 6 sets the solutions in the conclusion.

2. Literature Review

With positive forecasts, firms of all sizes are tuned to investment growth and hiring new employees [19]. With negative predictions, entrepreneurs face higher environmental uncertainty, are more sensitive to innovative projects and are less willing to take risks [19]. Companies stop hiring new people and investing [13], they reduce costs and often dampen research and development (R&D) programs [20]. With reduction of their risk tolerance, they also look for local sources known to them [21] and rely on internal reserves [22]. At the same time, because of the pressure to cut costs, they restructure production processes [23], and they can benefit from price stagnation as an advantage in investment [24]. Introducing a new product during the recession allows the company to gain a leading position in the eyes of the buyer, until the demand recovers [25].

The state of the economic cycle affects the developing process of industrial sectors across companies of different sizes. Large firms have the advantage of their economic strength, while small firms are more vulnerable. The ability to mobilize funds in favor of innovation is on the side of large firms. The smaller ones must, therefore, be better prepared for downturns [21]. Investing in innovation means gambling on the future [10], but the question is how much firms are willing to bear the cost and risk of innovation.

Many economic decisions, made by policymakers, firms, investors or consumers are often based on predictions of relevant macroeconomic indicators. Instead of gross domestic product (GDP) growth estimations, these users are interested in future consumption development when a turning point appears [26]. The accuracy of these predictions may have significant implications [27], as they are essential for business decision-making and for the effective macroeconomic policies [28].

Many authors [19,29–33] dealt with the forecasts of the crisis in 2008. The speed of economic change during the recession was a big shock to both politicians and businessmen. Their response to the oncoming crisis was not timely despite the use and combination of indicators [18], so the search for reliable tools for monitoring real-time economic developments continues [30].

The capability to respond to change in the economic cycle is related to the competitiveness of all companies. If they are able to estimate future developments, it provides them the opportunity to change their strategy in time. However, it may be difficult for small and micro businesses to track macroeconomic indicators. Nevertheless, if they join forces with other small firms in their field, a very effective cooperation can arise. So-called "coopetition", combines the advantages of competition and cooperation while the companies share the same market conditions [34]. Co-operation in the field of

future market conditions perception provide benefits to all firms involved [35]. The ability to share the cost of retrieving and processing information increases their efficiency [36]. Collaboration among competitors in the field of sharing information on the future development of the economy also brings a significant contribution to the planning of innovation activities. Furthermore, there is no risk of "betrayal" from a partner in coopetition in sharing future development information, such as in sharing information on technology or customer.

The main source of information for now-casting is BCS [37]. It serves the timely evaluation of the current economic situation as well as the correct estimate of the short-term outlook [18]. Demand for macroeconomic analysis for short time periods has increased [12,17], which Reference [38] attributed to shortcomings in macroeconomic systems. Dovern and Jonas [39] have shown that the disagreement rates of short-term forecasts tend to be lower than forecasts for longer periods and also that forecasters adjust their forecasts around turning points [32].

Different prediction models provide different results [16]. There are many reasons for this: The various phases of the economic cycle, the need to estimate unknown factors [27], the diversity of national economies, structural changes in the economy [16], the interdependence of economies [40], the length of time series analyzed [27], the selection of input indicators and also the determination of the weights in model [14,38]. In some models the monthly indicators need to be adjusted to quarterly ones, which erases the differences between months [18]. Regarding the reliability of these predictions, it is not proven which of the schemes is the best [18,37], and unexpected circumstances can play a part [28].

The greater amount of data does not always result in a better forecast [41]. As early as 2004, Hansson et al. indicated [42] that efficiency was becoming a desirable approach to predictions modeling. The systematic selection of key indicators from a vast amount of data deserves both theoretical and empirical research [30]. Simple models are popular because, according to Erkel-Rousse and Minodier [14], they often work as well as the more complex ones do, and every simple model prediction can be traced back to its beginning [18]. Acedański [28] points out that little is known about how well the forecasts for the near future predict.

The basis for estimating the expected economic development in the near future is the BCS [14,15]. The methodology is common to the member countries of The Organisation for Economic Co-operation and Development countries; it is called the Joint Harmonized EU Program of Business and Consumer Surveys [15]. Every month, the Industry, Construction, Trade, Services and Financial Services panels are asked about the attitude towards future economic developments [15]. This information is a part of a wide range of information provided by the government through the Czech Statistical Office (CZSO). Business cycle surveys are useful for industrial policy in a broader sense, as the company of any size can expand its external economic information portfolio.

Business survey data is well accessible, unbiased [17] and, above all, it is timely as they are issued two business days before the end of the reference month (as opposed to Gross Domestic Product (GDP) which is published by Eurostat 6 weeks after the end of the period) [15] (p. 22). The results of the business survey are published as separate indicators, or they enter into composite indicators, which are a part of the Joint Harmonised EU Programme of Business and Consumer Surveys, which is administrated by the European Union (EU). Business and consumer surveys are the tools for discovering future economic development, and they help protect the industry from precipitous changes in economic conditions.

There are quite a few models for predicting economic activity. Current literature suggests that different models have different ability to predict the near future correctly [16,18,27,28,30,37,38,40,41]. Major BCS users are banks, ministries and transnational organizations. Simultaneously, industrial firms play an important role in BCS problematics [12]. They are a part of the system of gathering the input data, and, at the same time, firms appear to be a crucial user of predictions. The companies themselves are the driving force of the economy, and their expectations are reflected in the economic activity.

The main aim of this article is to clarify whether the consistency of selected short-term indicators and subsequent developments differ depending on the stage of the business cycle. The examined period is between the years from 2003–2017. This time period includes several sub-phases of the economic cycle. An assessment of industrial orders in the Czech industry was chosen as an indicator of future development. It represents an unbiased estimate of industry representatives about the closest economic development. This indicator was compared with the performance indicator of a selected industry in several models. The models of comparison are uncomplicated, so that the businessmen from small firms can consider them comprehensible. After testing the level of matching of the indicators in the afore-mentioned models they were tested in the context of the economic cycle.

A specific sector of the Czech economy, mechanical engineering, was chosen to analyze the reliability of business cycle surveys. Mechanical engineering is an important part of the Czech economy for its long tradition and also for its position in the world markets (export 13th in the world, with production per person 8th in the world and consumption per person 7th in the world [43]).

3. Materials and Methods

The research question is: Does the reliability of selected business cycle surveys indicators depend on the stage of the business cycle?

3.1. Data

All input data come from the CZSO public database [44–46] whose survey methodologies correspond to the EUROSTAT methodologies. Input data are not revised nor seasonally adjusted. The Statistical classification of economic activities in the European Community (NACE) was used as the classification of industry data.

(1) The assessment of order-book levels (AOBL) [44] in the Czech industry represents the business cycle indicator. (2) Data representing economic development were GDP in manufacturing, which is called NACE C (GDP (C)) [45], (3) and industry-specific data were the new industrial orders (NIO) in machinery and equipment, which in terms of NACE classification is the NACE 28 (NIO 28 for the new industrial orders in machinery and equipment) [46].

Assessment of order-book levels for the Czech manufacturing industry is an indicator that expresses the balance between positive and negative answers to the question: “Do you consider your current order books to be . . . ?” There are three possible answers: "more than sufficient (above normal), sufficient (normal for the season) and not sufficient (below normal)“ [15] (p. 17). These forecast indicators are published immediately, at monthly intervals, according to the OECD methodology [15] (p. 22). In the Czech industrial demand estimation panel, there are 1000 managers of industrial enterprises falling within NACE 10–33 [47].

GDP NACE C is one of the sources of gross domestic product, namely GDP for the manufacturing industry, of which engineering is a part. It is published quarterly with the time delay of approximately 6 weeks [15].

New industrial orders NACE 28 (Manufacturing of machinery and equipment) are published monthly. This indicator has several positives in comparison to GDP; it is quickly available and based on actually realized industrial orders, not on expectations [26].

The business cycle phases are represented by periods significant to Czech industry. The year 2003 marked a slight economic increase, which was supported by the Czech Republic’s accession to the EU in 2004. The years 2005–2008 meant economic growth, which was slowed down by the global crisis. The subsequent recession since 2009 turned into a mild recovery in 2010. Then the recession returned for the next two years. Due to impending deflation, the Czech National Bank set a fixed Czech crown (CZK) to Euro (EUR) exchange rate, which helped growth. It continued after 2017, when the exchange rate commitment was canceled. Table 1 gives an overview of the period, duration, and measurement numbers that entered the analysis.

Table 1. Overview of periods and number of evaluated match measures.

Periods	Beginning of Period	End of Period	Number of Years	Number of Evaluated Measures for Quarterly Indicators	Number of Evaluated Measures for Monthly Indicators
1	2003	2004	2	8	24
2	2005	2008	4	16	48
3	2009	2010	1	8	24
4	2011	2014	4	16	48
5	2015	2017	3	12	36

The dependent variable in research was the reliability of selected indicators, which was evaluated in terms of match between prediction and real development. The independent variable was the period in which the match is monitored (see Table 1).

3.2. Procedure

The problem was analyzed in two insights:

1. Match level in models
2. Match degrees across models

3.2.1. Insight 1: Match Level in Models

In match level in models across time periods the dependent variable was trend matching (match/close match/mismatch) between assessment of order-book levels (AOBL) or GDP NACE C (CGP (C)) and new industrial orders of NACE 28 (NIO 28), and the independent variable was business cycle phases in time period 2003–2017 (see Table 1).

Trend Matching

It was examined whether the trend in the development between indicators was concurring. Trend matching was developed in several models on two levels of the economy, GDP (C) and NIO 28 and in three time intervals (1–3 months) between forecast and the performance indicator.

(a) Quarterly matching: In the trend matching assessment we worked with GDP (C) increments between quarters at time T_q and compared them with the AOBL forecasts for each month (M1, M2, M3) of the previous quarter $T_q - 1$.

(b) Monthly matching: In the trend matching assessment we worked with NIO 28 in one, two, and three months (M1, M2, M3) at time T_m following the AOBL prediction at time $T_m - 1$, resp. NIO 28 M1 for one-month increments after the forecast, NIO 28 M2 for orders in two months after the forecast, NIO 28 M3 orders increments three months after the forecast.

Figure 1 provides the scheme of the trend-matching breakdown in the insight 1 Match level in models as explained above.

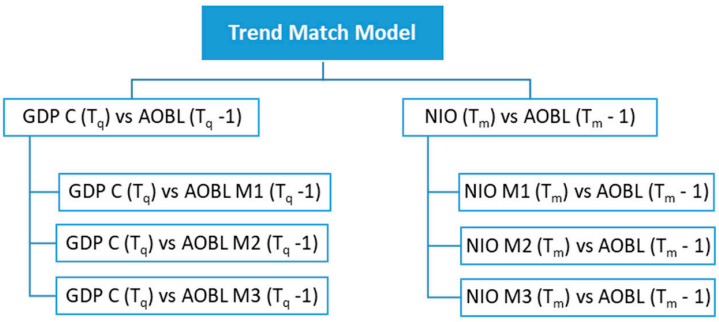

Figure 1. Match level in models of insight 1.

The relative frequencies of trend matching for the indicators described above were achieved by first evaluating the trend (three stages) between individual periods of individual indicators (growth/stagnation/decline), after which the consensus of the development of forecast indicators AOBL and the development of GDP (C), resp. NIO 28, was evaluated in three degrees: Match (both indicator trends match), close match (indicator trends do not match in one degree), and mismatch (indicator trends do not match in two degrees).

Figure 2 provides the scheme of the trend matching breakdown in insight 1 and the overview of the time periods. The time period is an independent variable, and the trend match model is a dependent variable.

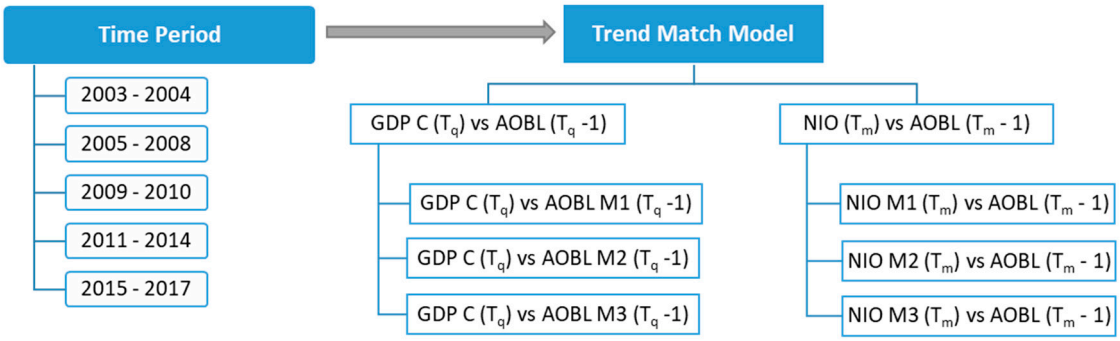

Figure 2. Match level in models—visualization of the variables of insight 1.

Hypotheses for Insight 1:

Null hypotheses of insight 1 covered the model's independence which meant that the result of the match is not dependent on the reference period, in other words: Match-degrees distribution (median distribution in a group) between selected business cycle indicator and subsequent economic development is consistent across the model in the reporting periods.

The specific null hypotheses for each model were:

H0(a). *Match-degrees distribution between AOBL M1 a GDP (C) is consistent across the model in the reporting periods.*

H0(b). *Match-degrees distribution between AOBL M2 a GDP (C) is consistent across the model in the reporting periods.*

H0(c). *Match-degrees distribution between AOBL M3 a GDP (C) is consistent across the model in the reporting periods.*

H0(d). *Match-degrees distribution between AOBL a NIO 28 M1 is consistent across the model in the reporting periods.*

H0(e). *Match-degrees distribution between AOBL a NIO 28 M2 is consistent across the model in the reporting periods.*

H0(f). *Match-degrees distribution between AOBL a NIO 28 M3 is consistent across the model in the reporting periods.*

The alternative hypothesis H1 to null hypotheses H(a–f) was that the match-degrees distribution is dependent on the reference period, resp. the distribution of medians in a group is not identical.

3.2.2. Insight 2: Match Degree across Models

In match degree across models the dependent variables were "match degrees" (match/close match/mismatch) across all the models studied and the independent variable were business cycle phases in the time period 2003–2017 (see Table 1).

Match level degrees are match, close match and mismatch. For each matching grade, its frequency was measured for all models in each period. Models with GDP (C) operated with a different frequency rate than models with NIO 28, and it was necessary to separate them.

Figure 3 provides the scheme of the match level degrees across models covered in insight 2.

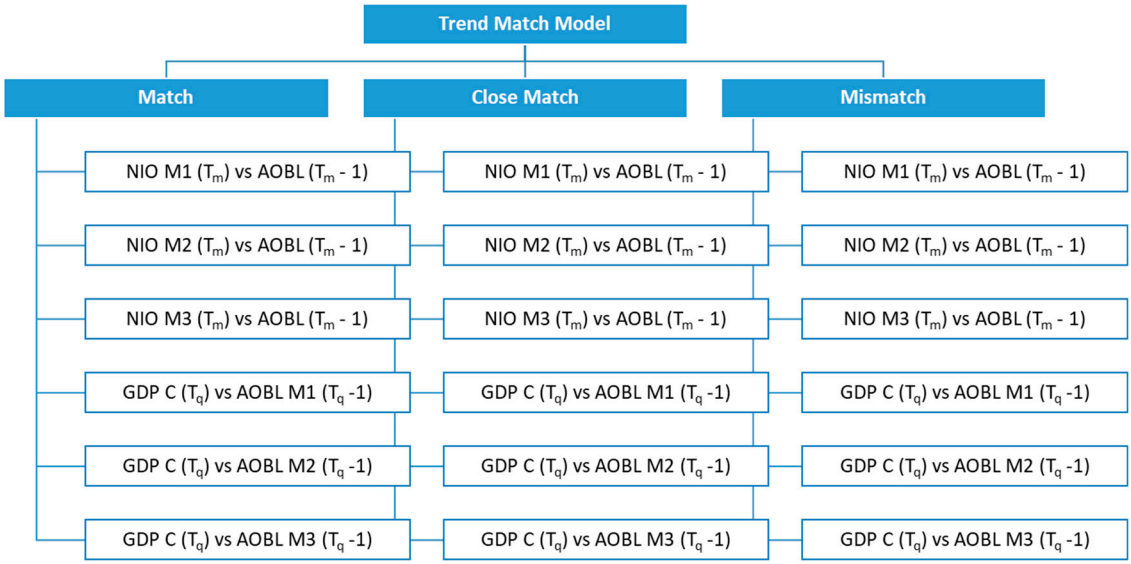

Figure 3. Match degrees across models—visualization of the variables of insight 2.

Hypotheses for Insight 2:

Null hypotheses of insight 2 covered the models' independence, which meant that the result of the match degree across models was not dependent on the reference period, in other words: The distribution of a match-degree of a model was the same across the monitored periods.

The specific null hypotheses for each model were:

H0(g). *The distribution of matches across GDP (C) models is the same in the monitored periods.*

H0(h). *The distribution of matches across NIO 28 models is the same in the monitored periods.*

H0(i). *The distribution of close matches across GDP (C) models is the same in the monitored periods.*

H0(j). *The distribution of close matches across NIO 28 models is the same in the monitored periods.*

H0(k). *The distribution of mismatches across GDP (C) models is the same in the monitored periods.*

H0(l). *The distribution of mismatches across NIO 28 models is the same in the monitored periods.*

The alternative hypothesis H1(g–l) was that the result of the match is dependent on the reference period, resp., the distribution of medians in a group is not identical.

Hypotheses Overview

The following table (Table 2) provides an overview of all hypotheses stated.

Table 2. Null hypotheses overview.

Hypotheses Number	Insight	Hypotheses Statement
H0(a)	1	Match-degrees distribution between AOBL M1 a GDP (C) is consistent across the model in the reporting periods.
H0(b)	1	Match-degrees distribution between AOBL M2 a GDP (C) is consistent across the model in the reporting periods.
H0(c)	1	Match-degrees distribution between AOBL M3 a GDP (C) is consistent across the model in the reporting periods.
H0(d)	1	Match-degrees distribution between AOBL a NIO 28 M1 is consistent across the model in the reporting periods.
H0(e)	1	Match-degrees distribution between AOBL a NIO 28 M2 is consistent across the model in the reporting periods.
H0(f)	1	Match-degrees distribution between AOBL a NIO 28 M3 is consistent across the model in the reporting periods.
H0(g)	2	The distribution of matches across GDP (C) models is the same in the monitored periods.
H0(h)	2	The distribution of matches across NIO 28 models is the same in the monitored periods.
H0(i)	2	The distribution of close matches across GDP (C) models is the same in the monitored periods.
H0(j)	2	The distribution of close matches across NIO 28 models is the same in the monitored periods.
H0(k)	2	The distribution of mismatches across GDP (C) models is the same in the monitored periods.
H0(l)	2	The distribution of mismatches across NIO 28 models is the same in the monitored periods.

Hypotheses Testing

In both parts of the research problem, there were categorical, explained variables (insight 1 match level in models; insight 2 match degree across models across models), and the Kruskal-Wallis test was used for hypothesis testing. It tested the assumption that the groups of variables examined could be characterized by the same median value of the explained variable, with the alternative that at least one median differed from the others [48,49].

The Kruskal-Wallis test statistics was used [49]:

$$H_C = \frac{H}{C} \tag{1}$$

where H value is [49]:

$$H = \frac{12}{N \times (N+1)} \sum_{i}^{k} \frac{R_i^2}{n_i} - 3(N+1) \tag{2}$$

The variables in equations for insight 1: N is the total number of all measured values (match/close match/mismatch in individual models), n_i is the number of values in i-th sample (per period) and R_i is the number of monitored periods.

The variables in equations for insight 2: N is the total number of all measured values (match degree across models), n_i is the number of values in i-th sample (per period) and R_i is the number of monitored periods.

Next the correction for tied ranks C was solved [49]:

$$C = 1 - \frac{\sum_{i-1}^{g} \left(t_i^3 - t_i\right)}{N^3 - N} \tag{3}$$

where g is the number of tied values, t_i is the number of ties for each rank value in i-th group. After that, the test value HC could be calculated. The resulting value of HC was compared to $X^2_{k-1}(\alpha)$ value, if HC $\geq X^2_{k-1}(\alpha)$, the null hypothesis will be rejected.

The computation was made in IBM SPSS Statistics software.

4. Results

4.1. Results for Insight 1: Match Level in Models

4.1.1. Relative Match Frequencies Based on The Models' Results

Tables 3 and 4 illustrate the relative frequencies of trend matching for the indicators described in Figure 1.

Table 3. Relative match frequencies based on results of GDP models.

Model	GDP C (T_q) vs. AOBL M1 (T_q -1)			GDP C (T_q) vs. AOBL M2 (T_q -1)			GDP C (T_q) vs. AOBL M3 (T_q -1)		
Time Period	**Match**	**Close Match**	**Mismatch**	**Match**	**Close Match**	**Mismatch**	**Match**	**Close Match**	**Mismatch**
2003–2004	0.38	0.25	0.38	0.63	0.13	0.25	0.38	0.13	0.50
2005–2008	0.44	0.19	0.38	0.44	0.13	0.44	0.63	0.13	0.25
2009–2010	0.25	0.13	0.63	0.25	0.25	0.50	0.38	0.13	0.50
2011–2014	0.31	0.19	0.50	0.31	0.19	0.50	0.25	0.25	0.50
2015–2017	0.25	0.25	0.50	0.33	0.33	0.33	0.33	0.25	0.42
2003–2017	0.33	0.20	0.47	0.38	0.20	0.42	0.40	0.18	0.42

Table 4. Relative match frequencies based on results of NIO 28 models.

Model	NIO 28 (T_m) vs. AOBL M1 (T_m -1)			NIO 28 (T_m) vs. AOBL M2 (T_m -1)			NIO 28 (T_m) vs. AOBL M3 (T_m -1)		
Time Period	**Match**	**Close Match**	**Mismatch**	**Match**	**Close Match**	**Mismatch**	**Match**	**Close Match**	**Mismatch**
2003–2004	0.38	0.33	0.29	0.21	0.29	0.50	0.42	0.29	0.29
2005–2008	0.50	0.15	0.35	0.60	0.08	0.31	0.42	0.15	0.44
2009–2010	0.38	0.04	0.58	0.38	0.04	0.58	0.42	0.08	0.50
2011–2014	0.40	0.21	0.40	0.46	0.10	0.44	0.31	0.19	0.50
2015–2017	0.44	0.19	0.36	0.44	0.25	0.31	0.39	0.25	0.36
2003–2017	043	0.18	0.39	0.45	0.14	0.41	0.38	0.19	0.43

Table 3; Table 4, which aggregate the relative trend matching frequencies, provided the following information at first glance: Predictions related to NIO 28 (see Table 4) showed a higher match rate than predictions related to GDP (C) (see Table 3) which means that more AOBL forecasts estimated the right trend of NIO 28 in the subsequent time period than the trend of GDP (C). There was also a noticeable difference between the models with different time shifts (the development within one month M1, two months M2, and three months M3 after the prediction). For GDP (C) (Table 3), the closer the forecast to monitored quarter (M3) was, the better the estimates were. With NIO 28 (Table 4), we can see that the predictions seemed most reliable (highest relative numbers in the Match column) for the following two months' time (M2) period.

Another observed characteristic which was provided by results in Table 3; Table 4 was the distribution of the number of matches/mismatches related to the periods for which the match was evaluated. It is obvious from the Table 3; Table 4 that forecasts were best in growth periods (most in 2005–2008), specifically the models NIO 28 M2, GDP (C) M3, and NIO 28 M1). On the other hand, most of the disagreements between forecasts and economic development fell into the period of economic downturn, especially in the years 2009–2010 (in all monitored categories). These descriptive data lead to the consideration that the result of the match or reliability of the prediction depended on the economic development and the expectations of the respondents were also under its influence. This consideration was also supported by literature; see the introduction.

4.1.2. Match Level in Models Testing

The test criteria results are presented in Table 5 for insight 1.

Table 5. Results for match level in models (insight 1).

Match Models	Kruskal Wallis Test (H_C)	Asymp. Sig.	df	Total N	Hyp. Number	Hyp. Supported
GDP C (T_q) vs. AOBL M1 (T_q -1)	1.813	0.770	4	60	H0(a)	Yes
GDP C (T_q) vs. AOBL M2 (T_q -1)	2.590	0.629	4	60	H0(b)	Yes
GDP C (T_q) vs. AOBL M3 (T_q -1)	4.276	0.370	4	60	H0(c)	Yes
NIO 28 M1 (T_m) vs. AOBL (T_m -1)	2.629	0.622	4	180	H0(d)	Yes
NIO 28 M2 (T_m) vs. AOBL (T_m -1)	8.844	0.065	4	180	H0(e)	Yes
NIO 28 M3 (T_m) vs. AOBL (T_m -1)	2.420	0.659	4	180	H0(f)	Yes

At the significance level p = 0.05 (at $X^2_4(0.95) = 9.5$) we did not reject any of the null hypotheses H(a–f) concerning the dependence between the match level in models and the time period. Modeled matches were not time-period-dependent. Independence could only be rejected at a significance level of p = 0.10 (at $X^2_4(0.90) = 7.8$) for H0(e) (the NIO M2 vs. AOBL model) and adopt an alternative hypothesis that stated that the distribution of medians in the observed groups was not identical, and therefore the prediction and performance match was time-period-dependent. With a radical decrease in the significance level, it would be possible to reject the null hypothesis of other models consecutively.

4.2. Results for Insight 2: Match Degree across Models

4.2.1. Relative Match Frequencies Based on The Match Degrees

Table 6 resulted from Tables 3 and 4 with the columns being rearranged according to the degree of matching. It still represents the relative frequencies as shown in Tables 3 and 4. The relative frequencies were left for demonstration of the proportion of trend matching. Table 6 supported the reasoning shown by Tables 3 and 4, namely that the result of the agreement or reliability of the prediction depends on the development of the economy, and the expectations of the respondents were under its influence.

Table 6. Relative match frequencies based on the match degrees.

Model	Match Degree	GDP C (T_q) vs. AOBL M1 (T_q -1)	GDP C (T_q) vs. AOBL M2 (T_q -1)	GDP C (T_q) vs. AOBL M3 (T_q -1)	NIO 28 (T_m) vs. AOBL M1 (T_m -1)	NIO 28 (T_m) vs. AOBL M2 (T_m -1)	NIO 28 (T_m) vs. AOBL M3 (T_m -1)
2003–2004	Match	0.38	0.63	0.38	0.38	0.21	0.42
2005–2008	Match	0.44	0.44	0.63	0.50	0.60	0.42
2009–2010	Match	0.25	0.25	0.38	0.38	0.38	0.42
2011–2014	Match	0.31	0.31	0.25	0.40	0.46	0.31
2015–2017	Match	0.25	0.33	0.33	0.44	0.44	0.39
2003–2017	Match	0.33	0.38	0.40	0.43	0.45	0.38
2003–2004	Close Match	0.25	0.13	0.13	0.33	0.29	0.29
2005–2008	Close Match	0.19	0.13	0.13	0.15	0.08	0.15
2009–2010	Close Match	0.13	0.25	0.13	0.04	0.04	0.08
2011–2014	Close Match	0.19	0.19	0.25	0.21	0.10	0.19
2015–2017	Close Match	0.25	0.33	0.25	0.19	0.25	0.25
2003–2017	Close Match	0.20	0.20	0.18	0.18	0.14	0.19
2003–2004	Mismatch	0.38	0.25	0.50	0.29	0.50	0.29
2005–2008	Mismatch	0.38	0.44	0.25	0.35	0.31	0.44
2009–2010	Mismatch	0.63	0.50	0.50	0.58	0.58	0.50
2011–2014	Mismatch	0.50	0.50	0.50	0.40	0.44	0.50
2015–2017	Mismatch	0.50	0.33	0.42	0.36	0.31	0.36
2003–2017	Mismatch	0.47	0.42	0.42	0.39	0.41	0.43

After the initial review of the Table 6, it could be found that the best matching results were in the years 2005–2008 and then 2015–2017. The worst match results were reported in the "crisis" period of 2009–2010 and also in 2011–2014. It could be summarized that the matching results in all three degrees of indicators' agreement were consistent across the periods.

4.2.2. Match Degree across Models Testing

The test criteria results are presented in Table 7 for insight 2.

Table 7. Results for match degree across models (insight 2).

Match Level	Kruskal Wallis Test (H_C)	Asymp. Sig.	df	Total N	Hyp. Number	Hyp. Supported
Match NIO 28	0.563	0.967	4	277	H0(g)	Yes
Match GDP (C)	0.692	0.952	4	67	H0(h)	Yes
Close Match NIO 28	0.664	0.956	4	93	H0(i)	Yes
Close Match GDP (C)	0.994	0.952	4	35	H0(j)	Yes
Mismatch NIO 28	0.988	0.912	4	221	H0(k)	Yes
Mismatch GDP (C)	0.527	0.971	4	78	H0(l)	Yes

At the significance level p = 0.05 (at $X^2_4(0.95) = 9.5$) we did not reject any of the null hypotheses concerning the dependence between the match degree results and the time period. Modeled matches were not time-dependent. Even when the level of significance was reduced, independence could not be rejected. The distribution of matches across periods in each model was similar. The distribution of close matches across periods in each model was similar. The distribution of mismatches across periods in each model was similar. The characteristics of economic conditions at different times did not affect whether the forecast coincides with the subsequent actual developments.

5. Discussion

Routing the cash flows in companies varies according to the stage of the business cycle. These changes affect innovation significantly. In bad times, the resources shift out of the development box, and in good times, they are back there [50]. In different sectors, innovation correlates with the business cycle in varying degrees.

In times of crisis and insecurity, when the tendency to invest generally decreases [21], the importance of business cycle surveys increases. The closer to the present the indicator is, the better it can be estimated [31]. In addition to GDP data, which is published with considerable delays, there is a need to assess the current economic situation as well as the correct short-term estimate [18] for timely assessment. Future prediction models work differently; Karel and Hebák [33] argue that the "best" predictive model may change over time, for example, during different parts of the business cycle, but also for different forecast horizons [51].

Usually, financial institutions and policy-makers are the main users of these indicators. However, our analysis focuses on less frequent relation, namely the association of business cycle surveys and industrial firms. In connection with these indicators, managers of selected companies are participants in the respondents' panel, thanks to which important development indicators are created. Yet, less is known about managers of private companies as users of these economic development indicators.

The arrival of the 2008 crisis was highly unexpected [18]. The authors have constantly been looking for the best tools to uncover future developments so that they can adapt their strategies to the new situation. For example, Reference [31] found improvements in estimation accuracy at times before turning points. Dovern and Jannsen [32] found that, in general, development is underestimated during recessions, while it is slightly overestimated in recovery periods, and, at the time of expansion, there are no systematic errors in predictions. In terms of investing in innovation during recessions, companies are making greater use of their own or local resources [4,22] while investing in new products rather than in processes. They are looking for new niches [4]. Companies that invested in the future in times of crisis were smaller firms [10] and had R&D departments before the crisis. However, these were relatively young companies (established after 2001), combining innovation with an exploration of opportunities in new markets, and their competitive strategy was product-based rather than price-based [21].

Can the influence of the period on the reliability of macroeconomic forecasts on selected indicators be confirmed? In this work, the main indicator analyzed was the assessment of order book levels (for the next 3 months) in industry. It represented the economic development forecast. The matching with subsequent reality was assessed against two different indicators at different levels of the economy.

The first one was the GDP for the manufacturing sector, and the second one was the new industrial orders for a specific industrial category, namely machinery and equipment (NACE 28). This allowed us to monitor compliance with a more general scale (GDP C), but also with a major industry of the Czech economy (NIO 28). The methodology for acquiring the indicators used in the research is internationally recognized.

Forecasting and actual performance overviews (see Table 3) showed differences in forecast reliability across different models. Forecasts were compared with sector GDP (NACE C), followed by comparison with a very specific indicator—new orders in machining (NACE 28). Forecasts for the new orders provided better matching with the consequent state in a particular industry (in engineering (NACE 28)) than in sector GDP. The GDP NACE C was supposed to be better matched on account of the representativeness of the respondent's panel (the manufacturing industry). A better prediction matching with a particular performance indicator can be explained by the nature of the chosen field of interest. Mechanical engineering (NACE 28) is an indicator of general industrial development, as the machines produced are subsequently involved in further industrial production. Furthermore, these surveys showed some imbalance in consensus at different times and, to some extent, confirmed, for example, the conclusions of Reference [32] that predictions are more reliable in times of economic growth, while less reliable during declines.

The challenge was to prove the statistical significance of this claim. By means of the non-parametric anova (Kruskall-Wallis test), it was shown that at different times the reliability did not differ significantly. If the significance level were reduced, one of the models examined would show a statistically significant period dependence, since the distribution in values varied within the groups (see Table 5). It was a model where the assessment of order book levels was compared with the development of new orders over the next two months. Another model, where dependence on the period would be demonstrated by further decreasing the significance level, was a model where the trends between assessment of book levels for the third month in a quarter and GDP for the following period were compared. These two match patterns were found to be the most matching prediction and performance ratios. When testing the distribution of data in individual model degrees (match, close match, and mismatch), significant variations in the context of different periods (see Table 6) have not been demonstrated. A cross-model test basically supported the results of deviation testing in models.

The question is how much business cycle data is actually used by businessmen. For example, Camacho et al. [30] draw attention to the fact that leading indicators research does not correspond to managers' work. There are also indications [52] that business managers do not use these indicators sufficiently and that awareness of indicators and their use needs to be disseminated, which the author plans to verify by further research with business managers of the Czech companies belonging to NACE 28.

The impact of business cycles on the existence of companies is related to whether the company is systematically building a competitive advantage. Small businesses may connect with other small businesses and use coopetition. This can happen within clusters that help small businesses become stronger and give them the opportunity to share some know-how. The usage of presented statistical data is an innovative way of working with the information of the general environment. Such innovation helps the companies orient themselves in the market better and to be better prepared for forthcoming change.

Methods of using business cycle surveys are universal across EU countries. Business cycle surveys are harmonized for all member countries and are used in similar forms in other economies around the world. Their broader use by corporate clients, especially SMEs, is therefore a topic of sufficient importance to make the topic worth noting. Companies can work with demand estimates (and other indicators of BCS) not only in their home country, but also in foreign trade.

Future estimation influences the choice of adoption of an appropriate strategy; in other words, adjusting decisions about the future of the company. It is very useful for managers and other stakeholders to be aware of which strategies perform well at different times. One option for companies

to survive business cycle fluctuations is to basically ignore the business cycle and work on innovation constantly. In difficult times, the companies should be flexible and focus on the product and the reliable after-sales service [53]. On the contrary, in times of growth, companies have enough time to prepare unconventional innovations with technological overlap into recession times [21]. These factors, in the context of an awareness of the future development of the economy, provide the company with the resilience and ability to be invulnerable and to survive difficult economic periods.

6. Conclusions

The reliability of the business cycle surveys (BCS) is constantly under investigation. The BCSs stand at the beginning of models to estimate future economic development and provide one of the most understandable indicators as it summarizes the survey responses. This makes the use of it quite attractive to managers of smaller companies. In the article, it was examined how the BCS estimates illustrate the future economic development with respect to the different phases of the economic cycle. Research has shown that at times of growth, indicators were more reliable than at times of decline.

The results are significant for all types of businesses, especially for SMEs. SMEs usually do not have a large administrative base, and the use of complicated indicators, where the manager is not able to imagine how they originated, is not very beneficial. BCSs serve to make better decisions on both tactical and strategic issues, and, especially, when deciding on future investments. The author considers it useful to present BCS indicators for their easy interpretation. Thanks to BCS, the manager can verify whether his decision would be influenced in the near future by a change in the trend of economic development.

The limitations of this study are that there is no model that predicts development completely reliably and with the same level of reliability in different parts of the business cycle. Furthermore, the use of indicators and research is based on the willingness of companies to add another item to the portfolio of information for decision making, which is not known or trusted by them. This is also the direction for further research by the author, who is going to deal with the approach of trade managers of engineering companies to the BCS indicators (do they know them, do they use them, do they consider them important?)

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Sustaining Innovation: Creativity among Employees of Small and Medium-Sized Enterprises and Students in Higher Education Institutions in Brunei Darussalam

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Abstract: This paper compares creativity experiences and perceptions among employees of small and medium-sized enterprises (SME) and students in higher education institutions (HEI) in Brunei Darussalam. The study was conducted through interactions and surveys to assess (i) understanding and practice of creative tools and techniques; (ii) creativity performance in teams and individuals and (iii) perception of creativity among 39 employees in SME and 68 students from HEI. Statistical analysis was carried out using Pearson's chi-square test for goodness of fit and Cramer's V test to estimate strength tests for correlation. The findings indicate a majority in both groups have not received prior instruction in creativity and that employees of SMEs have less interest in receiving creative instructions. There is consensus among both groups that group work will result in greater creative performance. Ambiguity of customer needs or requirement was a factor most often cited to impede creative performance of teams in SME. Results from this study were used to make recommendations to improve practice and learning creativity in SME and HEI.

Keywords: innovation; creative design; creativity education; knowledge acquisition; teamwork

1. Introduction

Successful industries and organizations depend on a culture of dynamic idea generation [1] and management of creative individuals. Organizations seek innovative design tools and best management techniques that will optimize value of their products and services. Managing individuals to build an economically dynamic enterprise requires skills and insights that challenge norms of an organization. Consequently, practices that reduce distractions and sharpen focus of creative workforce towards organizational goals are desired. The concept of creativity, associated with chaotic dynamism [2] at first glance, does not provide immediate support towards organizational goals. Hence, it receives passive attention and insufficient policy support necessary to foster its development even when creativity is recognized as fundamental to business success [3]. Traditional methods of conducting businesses are not sufficient to grow Brunei Darussalam's small and medium-sized enterprises (SMEs). Understanding, applying creative principles and processes, as well as design management strategies for the public and private industries are required. With increasing competition for survival and success, organizations cannot maintain a competitive edge by just reaching their target customers alone.

Product functionality has to maintain robust design that serves current and future needs [4]. The skill to invent a new, or transform an existing, product, services, event, or phenomenon into a marketable and thriving design has been key for strategic innovation and product development. Products and services that attract customers, sustain and captivate their interests are built on a platform of consistent evolution. Hence, industries that are not vibrant enough to continually seek cutting-edge techniques to achieve their goals and drawn customers will be left behind. Furthermore, there are challenges from a social point of view. Creative products have to provide socially useful solutions to problems. However, usefulness may not be sufficient if the novelty element is crucial, without which a product would not be creative, even though it might be valuable [5].

In corporate environments, design managers oversee development of products and services and manage the innovation workflow. They also have significant role to play in managing the articulation of business strategy, system of product brands and service values, requiring continuous improvement for customer satisfaction [6], and these often involve the application of design thinking, advanced technology, as well as the management of creative specialists. Csikszentmihalyi [7] noted that creative specialists can be "both rebellious and conservative" and alternating between "smart and naivety" yet they are the driving force for the advancement of the organization. Behavioral imbalances, distractions, and inconsistences are the greater internal barriers towards optimizing creative design strategies. Therefore, identifying and applying the right creative tools to achieve the appropriate management techniques cannot be over emphasized. SMEs that stimulate and sustain a culture of creative thinking will have open innovation and continuous improvement [8].

2. Key Literature Review

2.1. Definition of Creativity

Open innovation is paramount for an organizational performance and survival [9]. Technology, globalization, and increased competition created an environment in which creativity tools are needed in order to cope with situational and economic pressures and frequent changes [10]. Creativity is defined as the ability to produce original, novel, and unexpected work with high quality [11]; since innovation is the implementation of new ideas [10], creativity sustains open innovation. Creativity has traditionally been seen involving the 'four Ps'; namely, person, process, product, and 'press', i.e., social context [12]. Creativity is also defined as a lead to something useful [13]. Recently, realization of creative products has received tremendous attention as it is claimed that "the only coherent way in which to view creativity is in terms of the production of valuable products" [14]. According to Cropley et al. [5], the idea of "product" should be understood in a broad way; products are often tangible and may take the form of written documents, or of machines, buildings and other physical structures such as bridges, vehicles and the like. They can also be intangible such as plans and strategies in business, government, and more general thoughts or ideas—systems for conceptualizing the world—as in philosophy and mathematics or, indeed, all reflective disciplines.

2.2. How Creativity Works

Neil et al. [15] identified preparation, incubation, illumination, and verification as four essential processes to creativity. They discussed challenges of generating innovative ideas towards solving continuously emerging problems in a complex environment and for conflict resolution. Three workshops were designed to encourage different types of creative thinking—explorative, combinatorial, and transformational [15]. The first workshop encourages exploratory creativity, in which participants explore the space of possible ideas to create new ones. Although similar to brainstorming, they encouraged analogical reasoning, common in creative domains, to generate new ideas. The incubation period is needed to handle complexities where participants are introduced to problems and challenges. During a relaxation period, participants unconsciously and consciously combine ideas with a freedom that does not follow linear and rational thinking. Subsequently, a creative

idea suddenly emerges as they illuminate on strategies and concepts, often at the most unlikely times. This "eureka" effect has been widely reported in creative problem solving [16,17]. It is a necessity to explain why creativity is difficult, so participants knew the challenges they faced. The study supported the hypothesis that creativity can be induced and sustained when inhibitions of participants are removed and they displayed teamwork [15]. Separating exploratory and transformational creativity processes and techniques in different workshops left some ideas underdeveloped. They avoided this by structuring workshops around ideas rather than processes.

2.3. Stimulating Idea Generation Tools in Students of Higher Education Institutes

Tan [18] combines the idea of teaching creativity with learning outcomes to students of Higher Education Institutes (HEI). Certain topics were mapped out for studying creativity. The purpose was to empower the students to explore new dimensions of thinking about aesthetics as manifested in different culture throughout the ages by reading and interpreting a variety of creative works and philosophies. However, traditional teaching methodologies such as reading, lecturing, testing, and memorizing were not considered useful because these activities were not being 'creative' [19]. The concept was to allow radial and non-linear questions, assuming one has the inherent ability for creativity rather than just learning to be creative, encouraging personal observation and conclusion without being judged. Participants were encouraged to discuss their learning in line with similar thriving industries and be able to identify strategies employed by the industries. The study shows that even individuals who have little prior knowledge of creative techniques can be motivated to develop novel initiatives.

2.4. Individual Creativity and Team Work

Organizations face problems today that are too complex for one individual or a mono-disciplinary team to solve [1,20]. Therefore, the past decade has seen an increase in the use of multi-functional collaborative teams by organizations [21]. In response to the increased focus on team work, many collaboration techniques and technology solutions have been developed to enable teams to work together productively. Team collaboration refers to the joint effort of members in achieving a goal. De Vreede et al. [22] explored antecedents of team creativity. A theoretical model called the Team Creativity Model (TCM) was employed to explain the constructs that affect team creativity. They began by introducing the nucleus of their research which was how individual creativity of one team member could be enhanced to impact the entire team. Every member was encouraged to make input without thinking that their ideas were silly or less useful. The study posits that when team productivity is seen as a whole rather than an individual input, it empowers members to have a sense of responsibility and achievement which in turn triggers more creative efforts. It is widely agreed that creativity can be acquired and influenced [1,23]. Each creativity session focused on idea generations. Team creativity occurs during a social process of sense-making and collaboration where one individual's actions may inspire the team to devise and follow a more creative process to address the problem at hand resulting in higher levels of creativity. The extent to which individual members of a team are capable of generating creative ideas will determine the creativity performance of the team as a whole. Furthermore, creative individuals and experts in particular, are less likely to have difficulties or be uncomfortable expressing themselves, even under less than optimal conditions [23]. Thus, if teams have higher proportion of creative individuals who are experts, such teams are more likely to have a high degree of team creativity. People who could look at problems with a neutral objective were better able to generate suitable techniques and dynamic approaches. Another characteristic that enable individuals to be creative is the capability to suspend judgment and use a wide range of categories while coming up with creative ideas [10].

Cross-functional team working within organizations is often portrayed as the key to creativity and success of organizations. There is ample evidence from psychological research on teamworking of how diverse range of individuals can create, through synergy, ideas which go beyond what any single individual could have produced on their own [24]. Similarly, in 'Knowledge Management' perspective,

where there is an emphasis on knowledge creation and collaboration, interaction, and teamworking are seen to be crucial. For instance, the knowledge creation model developed by Newell et al. place significant emphasis on social process of dialogue and interaction [25]. In particular, dialogue and interaction occur over prolonged period so as to allow sharing of tacit knowledge which is essential for knowledge creation. The central idea is creativity develops from the *process*. The practice will add value to organization that has a culture of knowledge sharing where employees were driven to generate and share knowledge for the purpose of organizational improvement [26]. The employees are more motivated and willing to share their knowledge because they feel more valued for their intellectual capabilities and skills when they can see their contribution towards improvements in the organization.

Finally, individuals who remember large amounts of information more accurately also has the capability to be more creative than their counterparts [27]. Creativity is also influenced by an individual's knowledge in his or her own discipline [19]. Expertise and domain knowledge have been found to be important contributors to creativity. Complete novices tend to be less creative at first but, as they gain knowledge, their creativity increases rapidly. The study concludes that trust, willingness to share knowledge and friendly atmosphere helps an individual to be open to share knowledge and strengthen the team. Encouraging openness at work makes it more likely a greater number of employees will feel be able to make suggestions for improvement and challenge existing practice without fear of being snapped at, ridiculed, or punished in some way [28].

While no data appeared to challenge the TCM or hint at other constructs [22], further data collection from organizations in different sectors or from cross-organizational collaborations is required to more broadly examine the extent to which the constructs of TCM can manifest when applied to SMEs.

2.5. Strict Organizational Structure Can be an Inhibitor

A prior report suggested the relationship between climate for creativity and organizational structure [29]. Innovation is the successful implementation of creative ideas within an organization. Creativity, per se, would not lead to innovation. It must be coupled with conducive organizational climate to enable successful innovations. The zeal to understand the dynamics and complexities in managing innovation is partly attributed to rapid growth of market changes and increased diversity of consumers' behaviors and needs [30]. The research notes that creativity and open innovation have higher significance among small firms or SMEs since they constitute the largest number of business entities in any country's economy. SMEs are seedbed of innovation and various measures should be taken to further stimulate innovation activities among the SMEs [29]. In order to compete with larger firms, SMEs need to become more innovative. Creative employees who are placed in productivity-driven organizations with formal structures, time constraints, strict regulations, daily similar tasks, standardized workplaces, etc., may not be stimulated to show the desired creative behavior [31]. As such, these employees are less likely to come up with new ideas for product or process innovation. Therefore, flatter structures and simplified reporting procedures tend to give new ideas a better chance of getting off the ground as they are less likely to become bogged down in red tape of the committee-bound reporting structure [28]. Creativity is less common in an inward-looking organization than one that is more outward oriented and it is the latter which is better placed to capitalize on new opportunities. Conversely, providing challenging and trusting climate has the highest correlation with innovation and indicates sufficient leeway, trust and opportunities encourage novel solutions to challenging problems [29,32]. Fundamental creativity issues were dealt with but did not provide avenue of idea excitation. SMEs are the seedbed for innovation and have the potential to compete with bigger firms innovatively when well informed [33].

2.6. Conditions Surrounding SMEs in Brunei Darussalam

Brunei Darussalam is a Malay Islamic monarchy and an independent sovereign sultanate. The country is located on the north coast of the island of Borneo in the South East Asia. The 2015 census estimated the population to be about 417,000. Brunei's economy is supported largely by exports from

crude oil and liquefied gas. Oil and gas accounts for 48% of economic output [34]. With the aim of reducing dependency on oil and gas, the government developed a diversification plan that cuts across all the sectors of the economy. This action plan is known as Vision 2035—locally known as "Wawasan 2035" in Malay—defines what the government wants the landscape of the country in the near future and helps it prepare society's mindset to meet challenges [35]. The vision encapsulates a nation which will be recognized for the accomplishment of her educated and highly skilled people measured by the highest international standard; maintaining quality of life that is among the top 10 nation in the world and a dynamic and sustainable economy. At the heart of the plan is development of Brunei's SMEs which contributes 58% of employment and 22% of GDP [34]. Table 1 shows the SME distribution.

Table 1. Percentage establishment of different SMEs in Brunei Darussalam.

Type of Enterprise	Number of Employees	Proportion of Establishment (%)
Micro	1–5	52
Small	6–50	44
Medium	51–100	2
Large	More than 100	2

A total of 9302 registered business establishment in all sectors were reported in 2008, Figure 1 [34]. Out of these, 98.37% were active SMEs most of which are in the wholesaling and trading sector followed by those in the construction sector, mining, quarrying and manufacturing sector; community, social and personal services; and agriculture, forestry, and fishing, respectively [34]. One of primary focus of the Wawasan 2035 is to incorporate SMEs into regional and international markets [34,35].

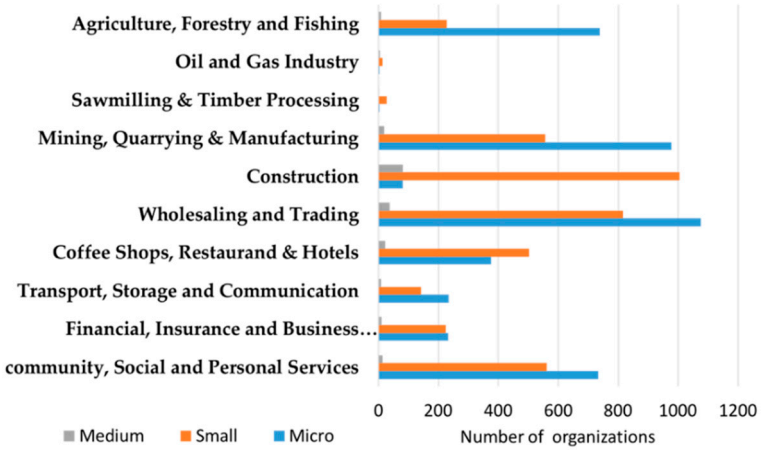

Figure 1. Distribution of SMEs across sectors in Brunei Darussalam.

3. Research Methodology

The aim of this study is to determine whether the experiences and perspectives of employees in SME and students in HEI are similar. To do so, factors affecting individual and team creativity generation among employees of SMEs and students in Higher Education Institutions (HEI) in Brunei Darussalam were investigated. Prior research work discussed in the Key Literature Review section clearly identified importance of learning creativity among students and employees in organizations. Furthermore, while recognizing the inherent creativity of individuals, creative processes are enhanced by interactions in teams. At the same time, there is an overwhelming number of SMEs in Brunei Darussalam.

In light of key findings in the literature, data collection is focused on four key areas affecting students in HEI and employees of SME, namely:

- Understanding and practice of creative tools and techniques;
- Creativity performance in teams and as an individual; and

- Perception relating to creativity.

3.1. Data Collection

Data were collected through interviews and questionnaires from SME employees involved in the product design and development process and HEI students. Table 2 lists the job functions and level of study of HEI students.

Table 2. Job functions of SME employees ($n = 39$) and study program of HEI students ($n = 68$).

Job Function	Percentage of Respondents (%)
Sales/Marketing	23
Education/Training	15
Other	21
Administration/Service	10
Engineering/IT	31
Study Program	**Percentage of Respondents (%)**
Diploma	3
Bachelor	63
Masters	25
Doctorate	9

Questions were designed to gather information on the four key areas in Section 3. A total of 39 completed responses ($n = 39$) were obtained from employees of 10 micro, five small, and five large SME. Similarly, 68 completed responses ($n = 68$) were received from students enrolled in three universities and one technical institution. Students from HEIs were in their final year of study. This was done with the assumption that they have carried out at least one project during the course of their studies and so would be able to identify with the questions adequately.

Visits to SMEs were conducted to gather in-depth on state of creativity in these organizations. During these visits, interviews were conducted with employees of SMEs directly involved in product design and development. Identical questions were used, as much as possible, when interviewing all participating SMEs to ensure consistency. Interview questions were designed to gather information on overall picture of the company and interviewees responsibilities with respect to creativity, understanding of the applications of creativity and innovation in the company. More specific questions were designed to obtain information on creative tools and techniques available in the organization and how these tools are used to empower creative teams or specialists.

3.2. Data Analysis

Interviews and questionnaires conducted among employees of SME and student of HEI generated nominal data. Pearson's chi-square $\left(\chi^2\right)$ test is used to determine goodness of fit between data sets from these two groups [36]. Pearson's chi-square test is selected as it is not only able to determine significance between nominal data sets but it can also provide information on which categories account for differences. This advantage allows for a richer analysis of data collected. In this study, the test was implemented on Microsoft-Excel software. The Pearson Chi-square test calculates χ^2 statistic through Equation (1):

$$\chi^2 = \sum_{i=1}^{N} \left(\frac{O_i - E_i}{E_i} \right)^2 \quad (1)$$

where:

χ^2 = Pearson's chi-square statistics
O_j = Number of observations of type i
E_i = Expected value of type i
N = Total number of observations

For any i-type and j-atttibute combinations, the expected value E_{ij} is defined by Equation (2):

$$E_{ij} = Np_ip_j \tag{2}$$

where:

p_i = Fraction of all observations of type i
p_j = Fraction of all observations with attribute j

The sample sizes for employees of SME and students of HEI are 39 and 68, respectively. To determine if there is any difference between data sets of employees and students due to effects other than sample size, one of the data sets has to be linearly scaled to the sample size of the other. Scaling was done by multiplying $\frac{39}{68}$ to values in the dataset from students to map to the sample size for SME employees. Pearson's chi-square test was implemented on transformed datasets from students. In this study, the p-value approach is used at a significance level of 0.05 adopted as a criterion. Since p-values for the chi-square statistic decrease with uniform sample size, the transformation essentially increases the likelihood of type I error.

The statistical strength of Pearson's chi-square analyses was assessed using Cramer's V test through Equation (3) [37]:

$$\Upsilon = \sqrt{\frac{\chi^2}{N(\kappa - 1)}} \tag{3}$$

where:

Υ = Cramer's V test statistics
κ = Number of rows or number of columns in the contingency table, whichever is less

4. Results

Employees in various SME organizations agree creativity is important to the success of their business and productivity. There was general agreement that to meet customer needs effectively, innovative strategy was needed. It was also agreed that it is essential staff understand and apply creative tools and techniques to solve emerging design development challenges. In addition, it is identified that the product development stage forms the basic stage of effectively satisfying the customer needs and companies experience the greatest challenge at this stage: namely, identifying the method of inquiry that help to gain clarity of what the customer needs, understanding technical thinking tools and design approach that lead to proper design mock up that will satisfy the needs. The two most common scenarios reported by SMEs were (i) the going back and forth when clients could not convey their design requirements and (ii) product specifications diverging from budgets; two factors which can be connected.

Our research shows these were the most frequently cited factors impeding creative processes during product development. Even though cost and time were factors, clarity of purpose ranked as the leading factor. A few companies have structures that help to resolve the challenge to a reasonable degree, while majority still struggle with it partly due to lack of experiences or lack of benchmark references. These factors are listed in Table 3. Each SME organization aspires to develop an innovative edge, and to possess and use techniques and tools of creativity. The interviews indicate interests by

each SME to strengthen their capabilities on creativity and to apply creative tools and techniques among their staff more extensively.

Table 3. Factors that discourage creativity in teams.

Item
• Customer communicates needs or requirement ambiguously
• Costs conflict with budget
• Customer demands frequent changes on a design
• Customer could not make up their mind
• Deadline is tight and customer is not willing allow more time
• Cash inflow is limited

4.1. Understanding and Practice of Creative Tools and Techniques

Two questions in the survey attempt to shed light on the above aspect. Responses to the question are summarized below. Bar graphs compare types of responses and present the raw data and those expressed as a percentage of the group.

Qn A: Have you participated or received instruction on creative design and management?

Figure 2 indicates a majority of employees of SME and students of HEI have not participated or received creative design and management. Results indicate 59% and 66% of Employee in SME and students in HEI, respectively, answered 'NO' to the question. In contrast, only 23% of employees in SME and 18% of students in HEI received some form of instruction. This suggests instructions in creative design and management are offered by HEI and SME for their students and employees, respectively, even though a majority of them have not received any instruction.

Qn B: Are you interested to receive additional instruction in creativity?

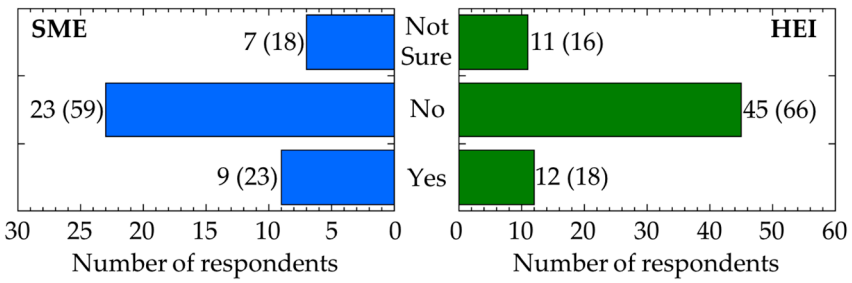

Figure 2. Responses to a question asking whether participants have participated or received instruction on creative design and management. The numbers in parenthesis are percentages.

Figure 3 shows about a third of employees in SME organizations are interested to receive additional instruction and almost half of them are "Not sure". In contrast, 59% of HEI students replied they are interested, while about a third are "Not sure". The percentage of employees of SME not interested is more than twice that for students in HEIs. These observations suggest that additional instructions will receive a better response in HEIs than in SMEs. This could reflect organizational constraints in SME which is not present in HEIs.

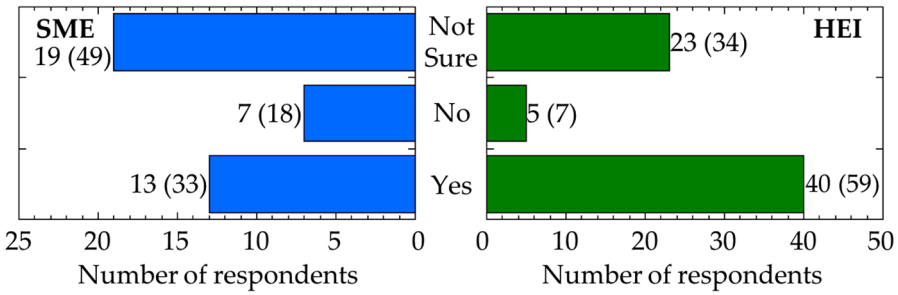

Figure 3. Responses to a question asking whether participants are interested to received additional instruction in creativity. The numbers in parenthesis are percentages.

4.2. Creativity Performance in Teams and as an Individual

One question in the survey focusses on the above aspect:

Qn C: Does group work result in superior creative performance relative to individual work?

Responses to the question are summarized in Figure 4. An overwhelming majority in both employees of SME and students of HEI groups agree that group work resulted in superior creative output. In contrast, about a quarter of respondents indicated individual work resulted in superior creative performance. This observation reinforces contributions of teamwork dynamics on creativity output. In addition, curriculum in HEI can be tailored towards team-based learning especially in subjects with significant creative content.

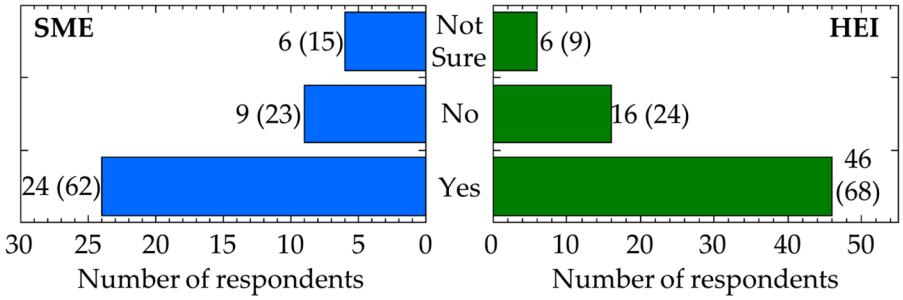

Figure 4. Responses to a question asking whether group work results in greater creative performance. The numbers in parenthesis are percentages.

4.3. Perception Relating to Creativity

Two questions in the survey attempt to gather information on the above topic:

Qn D: Does competition lead to greater use of creative tools and approaches?

Figure 5 indicates a majority of employees of SMEs and students of HEIs agree that competition will spur adoption of creativity tools and approaches. An overwhelming majority of employees in SMEs (54%) and students in HEIs (78%) agree that competition facilitates creativity among individual and teams within the organizations. Notably, the greater percentage (78%) of Students in HEIs compared to employees in SMEs (54%) that subscribe to this sentiment underline a higher degree of openness to competition among the former group and, perhaps, reflect lack of competition or regulations that hinder competitive forces in Brunei's industry.

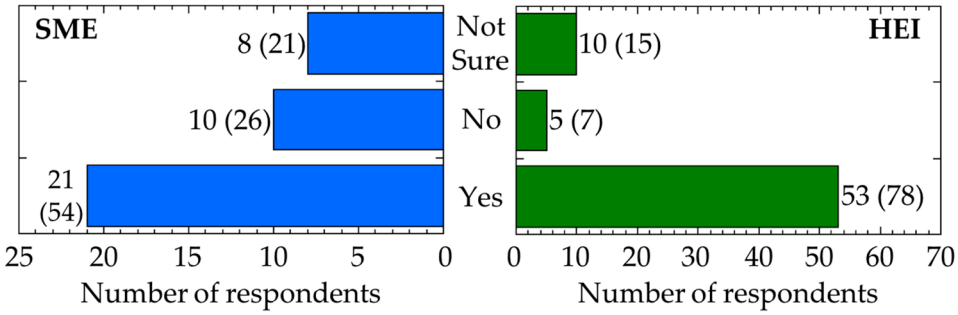

Figure 5. Responses to a question asking whether competition leads to greater adoption of creativity. The numbers in parenthesis are percentages.

Survey results indicate open mindedness is widely perceived to be associated with creativity as shown in Figure 6. 'Unconventionality' was the least associated with creativity among employees in SME with 10% while among students in HEIs, 'Novelty' was the attribute least associated with 7%. However, a majority in both groups selected 'Open-mindedness' as the attribute associated with creativity. Among employees in SMEs and students in HEIs, 36% and 40%, respectively, selected open-mindedness.

Qn E: Which attribute do you most associate with creativity?

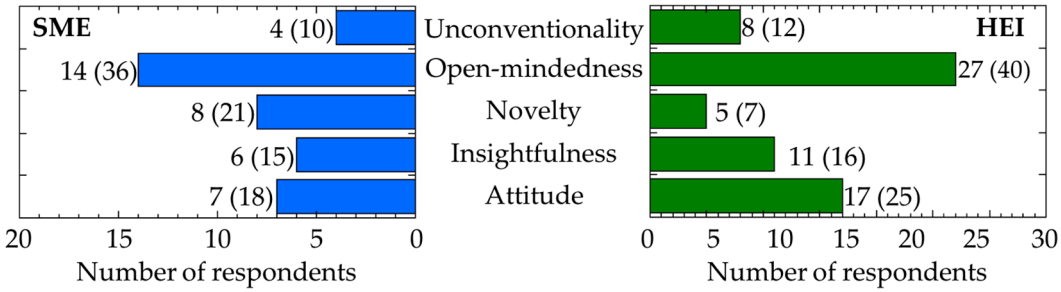

Figure 6. Responses to questions asking attribute most associated with creativity. The numbers in parenthesis are percentages.

5. Statistical Analysis and Discussion

Statistical analysis was performed on results presented in Section 4. Results of the Pearson chi-square $\left(\chi^2\right)$ test and Cramer's V test for statistical strength are presented in Table 4. The degree of freedom (Df) is defined as the number of choices of a variable less 1. For Qns A–D, there are three choices namely "Yes", "No" and "Not sure"; hence Df is 2 for these questions. The null (H_1) and alternative (H_2) hypotheses are:

H_1: *Responses from employees in SME are the same as those of students in HEI.*

H_2: *Responses from employees in SME are different as those of students in HEI.*

Pearson's chi-square $\left(\chi^2\right)$ test is used to determine similarity between responses of employees in SMEs and students in HEIs. Null hypotheses are nullified if $p-$value ≤ 0.05. The p-values for Questions A and C are greater than 0.05 hence the null hypotheses are not nullifable and H_1 is supported, as shown in Table 4. Similarly, for Questions B, D, and E, with $p-$values ≤ 0.05, H_1 are nullifiable and H_2 is supported. Cramer's V statistics for all questions are less than 0.3 which suggests weak correlation between responses of groups.

Table 4. Statistics of Pearson's chi-squared test and Cramer's V test.

Question	Df	χ^2	*p*-Value	Supported Hypothesis	Υ
A: Have you participated or received instruction on creative design and management?	2	0.480	0.597	H_1	0.078
B: Are you interested to receive additional instruction in creativity?	2	5.528	0.002	H_2	0.266
C: Does group work result in superior creative performance relative to individual work?	2	0.808	0.346	H_1	0.102
D: Does competition lead to greater use of creative tools and approaches?	2	6.045	2.1×10^{-5}	H_2	0.278
E: Which attribute do you most associate with creativity?	4	2.998	0.037	H_2	0.196

From Pearson's chi-square analysis of response to Question A, it can be inferred that employees of SMEs and students in HEIs have similar experience in that a majority of them have not received instruction in creativity. Indeed, much more staff and students of SMEs and HEIs, respectively, do not receive instruction on creativity compared to those who do. To remedy this situation, SMEs and HEIs and can offer instruction in creativity to a wider group of employees and students in their organization. However, students and employees will respond to additional instructions in different ways as revealed by statistical analysis and responses to Question B. It indicates if additional instructions in creativity are offered, greater acceptance will be received among students of HEIs than among employees of SMEs.

Statistical analysis of Questions A and B point to the need for human resource and skill development statutory bodies such as the Darussalam Enterprise (DARE) and for educational entities in Brunei Darussalam to review their programs and curricula to ensure instructions on creativity are sufficient. A greater impact can be expected if creativity is taught at HEI as students are more interested in attending such courses. Indeed, a university that implemented creativity courses reported a total of 260 students had taken such course within four semesters [18]. Re-invention among SMEs through initiatives to enlighten businesses on the use and application of creative design in product development is also suggested. However, since results of Question B indicate a lack of interest among employees of SMEs to attend creativity courses, regulations or incentives may be needed to compel or attract such employees to attend such courses such as through a skill-upgrading programs. As discussed in Section 2.3, even individuals who have little prior knowledge of creative techniques can be motivated to develop novel initiatives after attending introductory creative courses [18]. This dovetails with prior research that concludes creativity is a trait that can be learned and acquired [1,23]. The root cause for lack of interest among SMEs deserves further study. It is possible that a strict organizational culture, influenced by a structured societal framework, inhibits an open environment where employees can request to attend courses as indicated by prior works discussed in Section 2.5 [28,29].

Employees of SMEs and students in HEIs agree that group work results in higher creative output, as shown by analysis of Question C. Additionally, the Cramer's V statistics $\Upsilon = 0.266$ is among the highest although still weak for a correlation parameter. This is important especially for HEIs which should design learning activities using greater team-based approaches especially in modules with significant creativity content. As discussed in Section 2.4, the central idea is creativity develops from the *process*. For group work, the process is facilitated through close interactions, i.e., interactions with other group members. However, individuals have to interact with his or her environment which may be prolonged and so are hindered. Hence, analysis of results of Question C reinforces findings in the literature [10,23–25]. This outcome is also significant as it indicates that the practice and learning of creativity is enhanced by team dynamics. Hence, HEIs should design curriculum such that team-based approaches are used in activities, especially those with creative content.

A majority of employees of SMEs and students in HEIs agree that competition will spur greater adoption of creative tools and approaches, as shown by responses to Question D shown in Figure 5. However, Pearson's chi-square $\left(\chi^2\right)$ test show statistical difference between responses of these two

groups with a p-value of 2.1×10^{-5} as shown in Table 4. An analysis of the data show that the greatest contribution to the χ^2-value is the large difference in the proportion of those who chose "No"; 26% of SME employees and only 7% among HEI students. However, the Cramer's V statistics $\Upsilon = 0.278$ is the largest among all the questions on account of a majority in both groups choosing "Yes"; 54% of SME employees and only 78% among HEI students. Competition can be expected to stimulate improvisation necessary for innovation. It has been argued competition can have a dome-shape effect on creativity, which means it has the capacity to enact self-reliance necessary to emancipate originality and cutting-edge innovation both in industries and training institutions, but the trend of competition may also get to the extent where people will be afraid to invest both talent and capital, stifling creativity [38]. Competition among co-workers has been observed to diminish creativity while healthy competition between groups tends to maximize potential of groups. An economy largely dominated by cultural tastes may not respond well to competition and further study exploring effect of culture on competition in Brunei is recommended.

Open-mindedness received the highest number of votes among employees of SMEs (36%) and students in HEIs (40%) as the attribute most associated with creativity as shown in Figure 6. However, among the other four attributes, namely "Attitude", "Insightfulnes", "Novelty", and "Unconventionality", there were differences between responses of employees and students which resulted in large χ^2 value and a low p-value of 0.037, which is below the significance level. This result is significant as prior key literature findings show that ability to suspend judgment on ideas of others is an important trait of high performance teams [10]; as discussed in Section 2.4. The conceptual foundations of open mindedness were developed by Hare [39]. Open mindedness is defined as being genuinely concerned to avoid bias, wishful thinking, and other factors that tend or will compromise serious examination of evidence [40]; it also means "being ready to view one's conclusions, no matter how strongly supported, as completely revisable in light of further evidence given the fallible nature of knowledge claims" [41]. These contrast to making up one's mind in advance and that contrary views must be mistaken and, therefore, unacceptable. Open mindedness is a measure of tolerance, non-judgmental, and unbiased views. Workers can creatively perform significantly better if they understand that their views or ideas can be revised. This is especially so in light of changing or ambiguous client requirements or budget considerations which are often cited as factors that discourage a creative team as listed in Table 3. This will give creative teams or individuals confidence needed to delve in and formulate extraordinary concepts during product development cycle. Open minded teams or individuals will seek and tap from unlimited alternatives. However, knowing alternatives depends on exposure to prior instructions in creative design and management. Hence, lack of instructions in HEIs and SMEs will discourage creative thinking. Hence, diversification programs integral to Wawasan 2035 can be better implemented in an open-minded society.

Assessing creativity is a highly intricate challenge that is virtually impossible to be accomplished using a handful of parameters, especially when attempted at the national level. An economy largely dominated by cultural tastes may not respond well to competition and further study exploring effect of culture on competition in Brunei is recommended [42,43]. In this context, Brunei offers a unique opportunity to study effect and interplay between culture, competition and creative processes in SMEs due to the large number of SMEs in the country. Additionally, Brunei's culture combines Malay and Islamic tenets with strong emphasis on social order and has a culturally centralized society similar to those of other communities in East Asia, such as Chinese and Japanese societies. Culturally de-centralized countries have been reported to be more innovative than culturally centralized countries [44].

6. Conclusions

This research assessed creative processes among employees in small and medium enterprises (SME) and students of higher education institutions (HEI) in Brunei Darussalam through interviews with key personnel and surveys. Ambiguity of customer needs or requirement was a factor most often cited to

impede creativity in teams in SME organizations. Statistical analysis of responses from 39 students from HEIs and 68 employees of SMEs was carried out using Pearson's chi-square test for goodness of fit and Cramer's V test for strength test. Such analysis reveals that a majority of respondents in both groups have not received any instruction in creativity. In addition, more students are interested in receiving instruction in creativity than do employees. A majority (>60%) of respondents in both groups agree that group work results in higher creative performance. Similarly, a majority (>50%) of respondents in both groups agree competition will lead to greater adoption of creative tools and approaches. However, a significantly larger percentage (26%) of employees disagree relative to the students (7%). Additionally, there is a consensus among students and employees that open-mindedness is most associated with creativity although there is significant difference between the number of respondents for other attributes among employees and students. The findings were discussed the light of policy and operational level recommendations for SMEs and HEIs in Brunei Darussalam.

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