Open versus closed innovation and their effect on innovation performance, with the moderating effect of strategic decision-making

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by

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Abstract

This study focuses on the relationship between open and closed innovation to determine whether open innovation leads to improved innovation performance. The effects of two different types of strategic decision-making (centralized and decentralized) are included to assess whether companies can increase the effectiveness of their innovation activities by creating authority structures aligned with their innovation modes. Secondary data are drawn from Bruegel, which conducted the European Firms in a Global Economy (EFIGE) survey in 2010 and made a truncated dataset available, making it possible to conduct this study. Measuring innovation performance in terms of product turnover, intellectual property, and organization practice, the results show that both closed and open innovation expenditures positively impact innovation turnover, other measurement were not significant. Comparing these innovation modes shows a slight disadvantage for higher open innovation expenditures. The moderating effect of strategic decision-making shows that it is best to combine closed innovation with centralized decision-making to obtain higher innovation turnover results in a closed innovation mode. This study contributes to the field of open innovation by providing new insight into the effect of open innovation on different types of innovation performance. In addition, many studies have acknowledged the effects of different types of decision-making, and this study underlines which would fit particularly well with closed innovation for better innovation turnover.

Keywords: Open innovation mode, Closed innovation mode, Decentralized strategic decision-making, Centralized strategic decision-making, Innovation performance

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Preface

In this research, open and closed innovation modes are analysed to determine whether open or closed innovation has the greatest positive effect on innovation performance. In addition, a moderating variable, strategic decision-making, is used to assess which combination of centralized or decentralized decision-making with which innovation type will have the greatest positive effect on innovation performance.

This research is conducted in advance of the study Strategic Management at the University of Tilburg, the Netherlands. Based on ongoing innovation worldwide and rapid changes in products, I am interested in how companies can increase their innovativeness by combining different types of innovation with their company structures. This makes decision-making a fascinating subject, particularly regarding decisions that must be made quickly to gain a competitive advantage. In my working career so far, I have enjoyed observing the activities of some companies. Yet have seen constraints in their innovation strategies and the pace of innovation.

This topic is interesting for academics in management, who could use my findings to explore further the field of open innovation and strategic decision-making. Furthermore, managers can investigate their organizations and determine which mode of innovation best fits their structure or which structure best fits their innovation mode.

I would like to thank my supervisor, Professor Marco Testoni, for the communication and guidance while writing this thesis and conducting this study. Also I would like to thank Professor Ian McCarthy for all the necessary and concise feedback. As a master's student, the tools and facilities to which I had access during this thesis were made available by Tilburg University and Luiss Guido Carli University. Therefore, I am thankful that the university offered me the suitable materials to conduct this study. Lastly, I am thankful to the Bruegel organization for opening up their anonymized dataset for further research.

Yours faithfully,

M.H.P. Nieuwenhuizen

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1. Introduction

Open innovation is an essential driver for value creation, especially given the fast-paced demands of customers, technological development, and global economic trends (Henderson, 2017; Hamel, 2006). McKinsey has recognized the importance of innovation to unlock post-crisis growth after the COVID-19 pandemic (Bar Am, Furstenthal & Roth, 2020). Unfortunately, many companies fail to manage their innovation strategies effectively. These inefficiencies lead to slow adaptation to changing trends (Pisano, 2015; Hill, Tedards & Swan, 2011). Proper management of these risks and interdependencies must be built upon an innovation strategy to implement good practices and effective trade-offs (Pisano, 2015). Furthermore, to stay ahead of competitors, businesses must develop capabilities to move quickly towards innovative ideas, these ideas are negatively affected by inefficient decision-making approaches (Hill et al., 2021). Decision-making is closely related to a company's performance (Baum & Wally, 2003; Goll & Rasheed, 1997), and part of the organizational authority, which is an essential component of a firm's organizational design (Colombo & Delmastro, 2004). In addition, the research of Lichtenthaler, Hoegl, and Muethel (2011) recognizes the importance of decision-making, mentioning that to prepare for open innovation, organizations must design their organizational structures for it. Therefore, companies must make the appropriate decisions to create an innovation strategy that aligns with the organization and its environment.

Regarding to those innovation issues, the open innovation paradigm can be seen as an accelerator for the pace of innovation (Chesbrough, Vanheverbeke & West, 2006). Following an open innovation strategy, organizations must manage knowledge sharing, the level of control they hand to partners, and how to retain their core competencies (Enkel et al., 2009). A closer examination of the possible modes of innovation reveals a distinction between open and closed innovation as part of the strategic intent. Open innovation is a concept that focuses on collaborative processes involving multiple parties to exploit existing products and explore new products (West & Bogers, 2014; Chesbrough, 2003). Closed innovation is the opposite, with companies trying to innovate only within the organization (Herzog, 2011). Current studies show many advantages of Open Innovation, multiple studies mention that it leads to an increased level of innovation (Laursen & Salter, 2006; Chesbrough, Vanheverbeke & West, 2006). Because companies get more ideas, knowledge and expertise from external sources. Also, according to literature, the time-to-market of a new products is reduced (Laursen & Salter, 2006; Chesbrough, Vanheverbeke & West, 2006). Collaboration can speed up the innovation process, compared to the traditional closed innovation approach. Internal R&D spendings are a burden to organizations, Open Innovation can reduce the cost by sharing the innovation costs with partners (Dahlander & Gann, 2010). Since outside knowledge can be gained, it improves the competitiveness and access to new markets, because there is a higher probability of

recognizing emerging trends (Laursen & Salter, 2006; Dahlander & Gann, 2010). Lastly, within innovative ecosystems, Open innovation can increase the organizational reputation by creating certain partnerships (Cui & Wu, 2018).

However, there is a neglected part of Open Innovation studies, where many focus on the benefits; studies that show downsides and limiting factors are relatively less available (von Briel & Recker, 2017; Dahlander & Gann, 2010; Greco, Cricelli & Mignacca, 2022). The study of Greco et al. (2022) shows that a neglected part in their study is the recognition of failure by companies. On top of that, they find that success stories have different implications when it includes a high-tech company compared to a low-tech company. It is therefore interesting to note the differences in innovation performance due to closed and open innovation. According to previous literature, open and closed innovation have different benefits and costs (Felin & Zenger, 2013). A study by Felin and Zenger (2013) shows that governance, exploration versus exploitation, and the delegation of authority are factors influencing the effect of open versus closed innovation. The authors found that closed innovation could have advantages in multiple business context areas. The study results contradict the Chesbrough's (2003) open innovation concept, which states that greater openness in R&D leads to higher performance (Oakley, 2012). This contradiction shows that it is not definite that open innovation is always better, this is a reason to explore the open innovation paradigm further. A study from Clausen, Korneliussen, and Madsen (2013) also shows a trade-off between open and closed innovation, as demonstrated by trade-offs between exploration and exploitation at Norwegian firms. According to Hill et al. (2021), inefficient decision-making is one of the main drivers of failure in companies' actions towards innovation. According to previous literature, the allocation of decision rights is divided into centralized and decentralized structures and has a proven effect on organizational performances (Schiff, 1966; Laureiro-Martinez, Brusoni, Canessa & Zollo, 2015; Kannan-Narasimhan & Lawrence, 2018; Baum & Wally, 2003). With centralized decision-making, the authority for decisions is high up in the organization. In contrast, decentralized decision-making places decision-making authority at lower levels of the organization.

Examining the delegation of authority, specifically, shows that open innovation leads to decentralized decision-making (Colombo, Foss, Lyngsie & Lamastra, 2021) – but is decentralization, combined with open and closed innovation, more effective for innovation performance than centralized decision-making? That is the central question to be answered in this research. For answering this question, some previous studies already have shown some indications. Centralized and decentralized decision-making affect organizational approaches to risk-taking, procedures, structures, knowledge management, and governance (Colombo et al., 2021; Clausen et al., 2013). A recent study by Hill et al. (2021) shows that better decision-making can drive innovation. However, organizations should not let old habits stand in the way of creativity. The issue is that firms are desperately using new methods but struggle to quickly adopt new ideas. This outcome is primarily due to outdated and inefficient approaches to decision-making (Hill

et al., 2021). Based on this knowledge, this research focuses on the moderating effect of decision-making on the innovation mode – in other words, on the innovation performance relationship. Due to the global economic trends, in which organizations work closer together, innovation activities of organizations have become increasingly focused outwards (Dahlander & Wallin, 2020; Dahlander, Gann & Wallin, 2021; Bogers, Chesbrough & Moedas, 2018).

To gain know knowledge of the overall effect of strategic decision-making upon the Open/Closed Innovation – Innovation performance relationship, this topic will be addressed from a quantitative perspective, in which the Bruegel questionnaire will be used. The main reason is that this questionnaire contains comprehensive data from many companies in seven European countries. Furthermore, the study addresses strategic decision-making from an organizational level of analysis, where there is either centralized or decentralized decision-making. This research will explore the current knowledge of differences and complementarities in decision-making methods that improve innovation effectiveness in open and closed innovation. With this combination of subjects, this research aims to find the most effective method of decision-making within the company for different types of innovation. The intention is to diminish the gap between decision–making style and the factors that lead to a higher innovation performance with different innovation types. Through this primary focus, the theory of open innovation will be expanded and firms will gain insight into decision-making's ability to improve their innovation effectiveness. This research will address the limiting factors of Open Innovation regarding authority structures within an organization. Organizations implement this way of innovating since it helps the pace of Innovation.

2. Theoretical framework and hypotheses

This section discusses the theoretical background of the two innovation modes and decision-making. The current literature's strengths and limitations are discussed for each topic, with existing studies presenting contradictory results. In the sections for each innovation mode, hypotheses are generated to explain why specific relationships between the constructs of this study are expected. The first part of each sub-section explains the innovation mode and its effect on innovation performance. In the second part of each sub-section, the moderating effect of decision-making is discussed. Endingly, this section mentions why specific effects are expected to happen between the constructs within this study, leading to the generated hypothesis.

2.1 Open Innovation

At the start of this century, Chesbrough (2003) developed the theory of open innovation. Chesbrough (2003, p. 43) describes open innovation as follows:

"*Open Innovation means that valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well. This approach places external ideas and external paths to market on the same level of importance as that reserved for internal ideas and paths to market during the Closed Innovation era.*"

Chesbrough divides innovation paradigms into two modes: open and closed innovation. According to his theory, open innovation should be more efficient in the current century. While closed innovation worked well previously, it is now outdated. Since the theory's creation, technology has only advanced further with robotics, the blockchain, big data, cloud computing, and application programming interfaces (Dahlander et al., 2021). Open innovation is not a theory focused on only one level of analysis; as shown by Bogers et al. (2014), its effects and results can differ at multiple levels, including the individual level and the project level.

Furthermore, studies have explained the level of openness by diversifying the concept of open innovation. There are three types of open innovation (West & Bogers, 2014): A. inbound (search and integrate external knowledge); B. outbound (sell intellectual property and reveal new technology to the market); and C. combined open innovation of inbound and outbound (through strategic alliance or partnerships). Other studies make another differentiation based on either acquisition or exploitation, leading to the following two types of open innovation; external technology acquisition (ETA) and external technology exploitation (ETE) (Hung & Chou, 2013). According to Dahlander and Wallin (2020), the time to invest in open innovation is now. Through correct use of the business model, a firm can control what knowledge is brought

inside and what is allowed to go outside. In addition, this model reduces the costs of innovation, accelerates time to market, increases market differentiation, and leads to new types of revenue (Chesbrough, 2011).

2.1.1 Open innovation mode

Following the argumentation of Chesbrough (2003), a company builds more robust innovation capabilities when its openness increases. Open innovation is a multi-dimensional concept focusing on collaborative processes between multiple parties (for example, universities, companies, and government) to improve products (exploitation) and develop new products (exploration) (West & Bogers, 2014). An open innovation mode is focused on the inside and outside of the firm. Internal innovation can be accomplished by external innovation efforts following the open innovation theory. The business model is fundamental to open innovation (Chesbrough, 2003). To fully exploit openness and the business model, it is essential to make the best use of internal and external ideas, and IP management is essential (Herzog, 2011). Open innovation is becoming more important as every company can easily access public databases and online journals. These technological opportunities mean that knowledge monopolies are in decline, as many can access the knowledge online (Chesbrough, 2003). Multiple indicators show a shift from closed to open innovation. Chesbrough (2003) mentions the following four: the number of patents held by small- and medium-sized companies, the number of U.S. patents held by non-U.S. firms, increased R&D expenditure at smaller firms, and the increased amount of humans' resources capital spent on education. In an open innovation mode, internal R&D is focused on identifying the available external knowledge, filling gaps in knowledge that could not be obtained externally, integrating internal and external knowledge, and gaining additional revenue from selling knowledge (Chesbrough, 2003).

2.1.2 Closed innovation mode

The concept of closed innovation can be explained by the perception that successful innovation requires control. With that logic, the organization is internally focused and self-reliant (Herzog, 2011; Chesbrough, 2003). Internal focus means that the firm does everything by itself. Therefore, every innovation project exists out of the following three main steps: "*(1) can only enter the innovation process at the very beginning, (2) are developed using only internal resources and competencies, and (3) finally can only exit the process by getting commercialized via the firm's own distribution channels*" (Herzog, 2011, p.19). Open innovation is a continuum, with fully open innovation on one extreme and fully closed innovation on the other (Dahlander & Gann, 2010). Based on the respected research of Chesbrough (2003), four erosion factors are recognized in a closed innovation 'paradigm'. First, the increasing number of skilled workers makes it possible for all organizations to work on internal R&D because it is easier for competitors to access knowledge. Nowadays, companies can profit from the training and experience of their competitors. Second,

the venture capital market is more accessible. In the past, start-ups and small organizations had difficulty finding capital to fund their R&D. Funding start-ups is now a more considerable risk, as individual personnel with high levels of experience can quickly join new start-ups. Third, the option of external ideas has not yet been developed in larger organizations. As product life cycles are declining while external options grow, organizations need to increase their rate of knowledge processing. The growth in external opportunities increases established companies' risk of inability to explore new markets.

Lastly, external suppliers have become more trained, are of higher quality, and have generally become more advanced. With closed innovation, this pool of knowledge is not used. These sources of erosion are restricting closed innovation organizations from self-reliance and implicitly suggest that firms must hire the best personnel, be first to market with an idea originating from within the firm to win the competition, lead in R&D intensity, and have restrictive IP management (Herzog, 2011).

2.1.3 Contradicting effects open innovation

In the current literature, many theories suggest that open innovation intentions do not necessarily lead to higher innovation performance, as specific characteristics of a firm influence the effectiveness of openness. Audretsch and Belitski's (2022) study shows that open innovation is limited mainly to the creative industries, and the limits of open innovation increase when a firm operates in international networks. Another underestimated aspect of the innovation mode is managers' decision-making to support knowledge collaboration (Audretsch & Belitski, 2020). This argument is further supported by the research of Kobarg, Stumpf-Wollersheim, and Welpe (2019), who show that at the project level, innovation collaboration could be influenced by organizational level analyses, suggesting that knowledge, managerial decision-making, and organizational readiness for openness influence open innovation outcomes. In addition, the extensive research of Herzog (2011) has found some contradicting results regarding the implementation of open innovation. Herzog (2011) recognized that the underlying innovation culture must be changed to exploit open innovation fully. The innovation strategy must fit the organizational culture. Another outcome shows that companies must avoid the "not-invented-here" (NIH) syndrome[1] and the "not-sold-here" (NSH) syndrome[2] (Lichtenthaler et al., 2011). Another limitation for open innovation is when organizations face highly complex issues within their industries, following a closed innovation strategy offers more advantages during the development of innovations (Almirall & Casadesus-Masanell, 2010).

[1] Not invented here syndrome in open innovation is a negative attitude towards inbound open innovation. Employees with a NIH syndrome have the tendency to focus only on the internal development of technological knowledge. These employees do not want to acquire technology from other organizations (Lichtenthaler et al., 2011)

[2] Not sold here syndrome in open innovation is a negative association with transferring technology of the company to other organizations. A NSH-syndrome is limited by the experience with outward technology transfers (outbound open innovation) (Lichtenthaler et al., 2011)

Moreover, the costs of open innovation are especially high when it loses its freedom. For example, a firm might recognize new product features, but be unable to start as the innovation focus is controlled by other firms that want to maximize their profits. Nevertheless, open innovation enables the discovery of areas that would otherwise never have been explored (Lichtenthaler et al., 2011). In addition, a company cannot simply start with open innovation without adequate preparation, as many fail. This failure has to do mainly with the necessary steps to take: managers should communicate the open innovation strategy, and top management should support this strategy, create a sound incentive system, design the strategy's organizational structure, and institutionalize open technology transfers in the culture (Lichtenthaler et al., 2011).

2.1.4 Innovation performance

In this study, the dependent variable chosen is innovation performance. Existing literature highlights the advantages of using innovation performance as a measure over alternative performance metrics in open innovation studies (Chesbrough, 2003; Laursen & Salter, 2006; Lichtenthaler, 2009). Firstly, innovation performance provides a tangible assessment that effectively reflects the effectiveness of open innovation and the actual outcomes of innovation. Secondly, innovation performance is closely aligned with organizational goals, enabling organizations to leverage open innovation to achieve their innovation objectives. Lastly, the measurement of innovation performance holds managerial relevance, providing valuable insights for managers and decision-makers that are actionable and enable informed decision-making.

2.1.5 Open innovation mode and innovation turnover

In general, open innovation leads to higher performance in innovation, as shown by the literature review of Zhao, Sun, and Xu (2016). Critical factors for this relationship are technological abilities, relational ability, absorptive ability, knowledge transfer, ecosystem, corporate culture, and external environment. Furthermore, Chesbrough (2003) states that higher openness generally leads to higher innovation performance. However, some contradictions can be found in the applicability of this theory, as multiple studies show an inverted U-shaped relationship between open innovation mode and innovation performance (Kobarg et al., 2019; Laursen & Salter, 2006). One such study is by Kobarg et al. (2019), which shows that this relationship depends on the breadth of partners (number of collaborations) and the depth of these collaborations (the intensity of interaction). If a firm goes beyond the peak of innovation performance, this performance will decrease, resulting in an inverted U-shaped relationship. Therefore, degree of openness is an essential factor in the impact of an open innovation mode on innovation performance (Kobarg et al., 2019; Laursen & Salter, 2006). Although some studies find this inverse U-shaped relationship (Kobarg et

al., 2019; Laursen & Salter, 2006; Greco, Grimaldi & Cricelli, 2016), they all recognize the potential positive influence of open innovation. Therefore, it is proposed that open innovation does have a positive impact on innovation performance, leading to the following hypothesis:

H1a: An open innovation mode is positively related to innovation turnover.

2.1.6 Closed innovation mode and innovation turnover

Innovation activity is vital for an organization. A proper balance between open and closed innovation is essential, in the light of work of Enkel et al. (2009), as too much openness can negatively impact the success of the organization's innovation. Moreover, the research of Bae and Chang (2012) notes that performance level is relatively higher in open innovation firms than in closed innovation firms. Therefore, it is suggested that closed innovation leads to higher innovation performance than not adopting an innovation mode. However, according to multiple studies (Chesbrough, 2003; Chesbrough, Haverbeke, & West, 2006), closed innovation has reached its limits, as the knowledge landscape cannot be fully used with a closed approach.

Companies must prepare to shift from closed to open innovation, as an open approach is complex and thus not easily managed (Lichtenthalen et al., 2011). Not every company can manage open innovation, and some will achieve better performance following a closed innovation mode. Therefore, due to the still ongoing shift in the paradigm from closed to open innovation (Lichtenthaler et al., 2011; Chesbrough, 2003) and the general importance of an innovation strategy (Pisano, 2015), the following hypothesis is proposed:

H1b: A closed innovation mode is positively related to innovation turnover .

2.1.7 Open versus closed innovation mode and innovation performance

As the concept of open innovation grows and the number of academic insights in this area increases, it becomes clear that open innovation's effectiveness, efficiency, and R&D productivity are better than those of closed innovation (Bae & Chang, 2012; Ili, Albers, & Miller, 2010). Another significant shift in the mobilization of technology and IP is that necessary knowledge is no longer available only to a few large organizations. This shift makes it necessary to obtain knowledge outside the organization and demonstrates the importance of opening up (Inauen & Schenker-Wicki, 2011). Another interesting study by Hung and Chou (2013) shows that acquiring external knowledge (or ETA) leads to higher innovation performance.

On the one hand, open innovation can produce limited effects. The same study by Hung and Chou (2013) shows that open exploration does not lead to higher firm performance. On the other hand, Lichtenthaler's (2009) research shows that open exploration leads to higher innovation performance. Moreover, the results

of Audretsch and Belitski's (2022) research recognize two other limitations: in the creative industry, openness is limited as managers in these industries have to be open and must engage with the local environment, and its limits increase when operating in international networks as the local region is an important factor for the optimal use of knowledge spillovers. Abhari and McGuckin's (2022) research also show multiple limiting factors for open innovation in organizations, as profitability depends on the presence of co-governance as the community becomes less restricted to standard procedures. The only way to survive in an open innovation mode is via engagement mechanisms[3]. Although there are some limitations to open innovation (Hung & Chou, 2013; Abhari & McGuckin, 2022; Audretsch & Belitski, 2022) and there is an optimum level of openness (Laursen & Salter, 2006), a higher level of open innovation is proposed to have a more positive effect. Therefore, the following hypothesis is proposed:

H1c: An open innovation mode has a higher positive effect on innovation turnover compared to a closed innovation mode.

2.2 Strategic decision-making

It is generally hard for individuals or different departments with overlapping but conflicting objectives to cooperate (Ouchi, 1979). Therefore, organizational design is focused on the alternative organizational structures because control is an important and, in some cases, neglected part of organizational design (Eisenhardt, 1985). Cummings (1995) recognizes that decentralization and centralization must be balanced; various combinations may provide the optimum design for control and authority. The question of centralization or decentralization is a continuous movement in society (Cummings, 1995) and, therefore, interesting for the open innovation trend. Following Zannetos's (1965) principles, the following characteristics of decentralized structures can be determined: A. a company has created economies of scale via specialization of the same functions and entities and has a continuous technological learning process; B. the financial cost of communication channels; C. the level of uncertainty, partial failure, and instabilities; D. motivational reasons from a psychological perspective; E. the decision-making time horizon and sensitivity; and F. the type of task and its characteristics. As these determinants show, the degree of centralized or decentralized decision-making impacts the entire decision-making process and organization. All these factors can be considered while making strategic choices, and every decision is different as they first must be interpreted and grouped into the right field, after the grouping it depends on routine decisions or non-routine which need a different skillset, as shown by Rosenzweig (2013). Rosenzweig's (2013) study divides strategic decisions into four categories: placing competitive bets, managing for strategic success,

[3] Engagement mechanisms are ways at operational level to recruit innovation partners whom are qualified and productive for a collaboration. Good partners are critical for the open innovation process (Abhari & McGuckin, 2022).

making judgements and choices, and influencing outcomes. These are scaled for absolute or relative performance and the level of control (low or high).

2.2.1 Costs and benefits of centralized versus decentralized strategic decision-making

The decision-making process impacts organizational performance, as shown by the study of Wally and Baum (2003), who focused primarily on strategic decision speed. Specific characteristics of centralized decision-making have advantages and disadvantages. According to the research of Fredrickson (1986), the level of centralization impacts the following factors: the number of top management executives involved in the strategic decision-making process; orientation focused on positive goal achievement; and the basis of actions generated by a company in rational strategic choices. In an environment with changing technologies, these rational strategic choices are best to be decentralized (Aoki, 1986).

The centralization process creates greater coordination of strategic actions (Fredrickson, 1986). Another positive effect of centralization is that it increases the likelihood that a strategy will become a proactive, opportunity-seeking process (Mintzberg, 1973; Carter, 1971). With a small, dominant group, strategic actions are based on the future domains of the company instead of the constraints of the decision-making process (Simon, 1964). Moreover, making decisions in a smaller group facilitates strategic choices and creates a rational actor to explain strategic actions in comparison to broader groups as is the case with decentralized decision-making (Fredrickson, 1986). With decentralization, authority is based upon joint decision-making, and involving many people is more difficult than exercising centralized authority. Considering all conflicting desires could be time-consuming and because of time constraints, managers might have to force decisions, which could lead to demotivated employees (Malone, 2004).

A constraint of centralized decision-making is that the cognitive capabilities of the top management will be of primary importance in developing the strategic process. If these capabilities are lacking, the organization will suffer (Fredrickson, 1986). Another potential issue regarding centralization is Mintzberg's (1973) recognition that any strategic issue can emerge from any level in the organization. Top management is not necessarily first to recognize strategic problems. However, strategic problems and opportunities will remain unrecognized until they appear at the top, leading to a delay in the start or even complete failure of the company’s strategic actions in innovation (Fredrickson, 1986). One approach is to focus managerial energy on a limited number of issues to achieve high strategic performance. If managerial energy is poorly allocated, the firm will engage in too many or too few communication channels (Ocasio, 1997). Child (1984) recognizes that decentralization within firms is more flexible than centralization and can therefore enable quick reactions to changing local conditions. Another benefit of decentralization, according to Malone (2004), is that it stimulates motivation and creativity. Finally, decentralization allows more people to work on the same issue and combine multiple capabilities (Malone, 2004).

2.2.2 Contradictory effects of different types of decision-making on innovation performance

Innovation is vital for business, and decision-making impacts the effectiveness of innovation. According to the research of Siggelkow and Rivkin (2006) in general innovation studies, decision-making could have a high impact on a firm's performance. The authors state that the interdependencies between a department and its managers result in the neglect of alternatives during the innovation process, and employees' low-level exploration for new innovations could result in even worse firm performance, as there is no focus on finding new ways to gain revenue. A high level of decentralization in the innovation process could reduce a firm's exploration, leading to lower innovation performance. However, other research by Thompson (1965) mentions that centralization decreases novelty within a firm, lowering innovation capabilities. In general innovation studies, multiple researchers recognize that decentralized decision-making during the innovation process positively influences innovation performance (Zabojnik, 2002; Malone, 2004). Also, in MNE (multinational enterprises) research, the more decentralized authority is diversified to the control of the subsidiary of the corporation, the higher the product innovation performance (Beugelsdijk & Jindra, 2018). In sum, there are multiple contradictions in the effect of decision-making authority and innovation performance.

2.2.3 Strategic decision-making and open innovation mode – innovation performance relationship

According to multiple studies focusing on innovation overall, decentralized strategic decision-making is expected to be the most efficient for innovation performance (Zabojnik, 2002; Malone, 2004). The research of Liu, Lv, Ying, Arndt, and Wei (2018) mentions that decentralization with a formalized structure positively impacts an organization's innovation capabilities. In this context, decentralization positively affects creativity and innovation and, therefore, is particularly interesting in product development departments (such as product design, information technology, and engineering) (Malone, 2004). Giving control in open innovation to these departments could, therefore, lead to better product development.

Colombo et al. (2021) mention multiple contingencies that suggest that open innovation and decentralized decision-making might have different impacts on performance depending on the firm's strategy (Love, Priem, & Lumpkin, 2002). Furthermore, recognizing strategic issues might be a problem in centralized decision-making (Mintzberg, 1973). Open innovation is focused on the business model, so recognition of strategic issues would be too late if they were not communicated to top management. A lack of communication could potentially destabilize the organization's innovation performance.

These arguments would suggest decentralized decision-making as the best option in an open innovation mode. However, as shown from general innovation research, there is conflicting evidence of decentralization's impact on innovation. First, one could argue that open innovation is a crucial strategic activity of a firm (Chesbrough, 2003) and, therefore, that top managers must exhaustively control it in a

centralized structure (Fredrickson, 1986). Second, actions taken in a centralized structure focus on the organization's future, which means the strategy becomes proactive. This proactivity would prevent the organization from focusing on unnecessary projects, which could diminish the potential loss of IP in the case of open innovation. Furthermore, as recognized in the paper by Hannen, Antons, Piller, Salge, Coltman, and Devinney (2019), not-invented-here syndrome as a decision-making error could lead to resistance to external knowledge. Therefore, this syndrome could affect the impact of open innovation on innovation performance. This issue could become greater in a decentralized organization that works via joint decision-making, making it possible for every employee influenced by not-invented-here syndrome; this could delay the innovation progress and make centralized decision-making more effective.

Considering all these arguments, it is expected that the combination of open innovation and decentralized decision-making has more complementarities for higher innovation performance, and the search for external knowledge will be more effective than with centralized decision-making. This leads to the following hypothesis:

H2a: Centralized strategic decision-making negatively moderates the positive relationship between an open innovation mode and innovation turnover.

2.2.4 Decision-making and closed innovation mode – innovation performance relationship

Colombo et al. (2021) recognize that innovation decisions are delegated less often to lower hierarchy levels in a closed innovation context. Suppose strategic decision-making is centralized and operational decision-making is decentralized; Baum and Wally's (2003) study shows that this division has a positive influence on firm performance. This argumentation can be combined with Pisano's (2015) assertion that organizations need an innovation strategy for optimum performance. Centralized decisions for innovation could improve performance if they were recognized as strategic decisions. In addition, in a closed innovation environment, the company must seek opportunities on its own (Herzog, 2011), and centralization leads to a more 'opportunity-seeking' focus (Mintzberg, 1973; Carter, 1971). Combined, these approaches can lead to higher innovation focus and potentially to higher innovation performance.

Furthermore, regarding the speed disadvantages of decentralized decision-making, innovation speed decreases because of the collaborative decision-making process (Malone, 2004). Herzog (2011) recognizes closed innovation as an innovation mode that wants to achieve ‘first-to-market’ status. A slower process is contradictory with a first-to-market approach within the closed innovation mode. In closed innovation, this would further reduce creativity, as people would be demotivated by managerial decisions and the mismatch within the company's control structure (Amabile, 1998; Pisano, 2015).

With centralized authority, there is also a risk that the top management will completely miss an opportunity (Fredrickson, 1986). With decentralized decision-making in a closed innovation context, this effect could be compensated for because other personnel would recognize the potential opportunity. In closed innovation, this effect would lead to missing innovation activities necessary for the organization's future performance. In addition, the research of Liu et al. (2018) recognizes that centralization of decision-making moderates the effect of improvisation and innovation capabilities. This would limit centralization's level of creativity and improvisation, leading to lower innovativeness. Weighing all arguments against each other, centralized decision-making in a closed innovation environment has a higher positive effect than decentralized decision-making, which leads to the following hypothesis:

H2b: Centralized strategic decision-making positively moderates the positive relationship between a closed innovation mode and innovation turnover.

2.3 Conceptual framework

Based on the proposed hypotheses, the following conceptual framework can be established (see Figure 1). Open and closed innovation modes can be separate (hypotheses 1a & 1b) or combined (1c). Strategic decision-making is based on two extremes (either centralized or decentralized) (hypotheses 2a & 2b). Strategic decision making is therefore explained by, the base variable, centralized strategic decision-making in this framework.

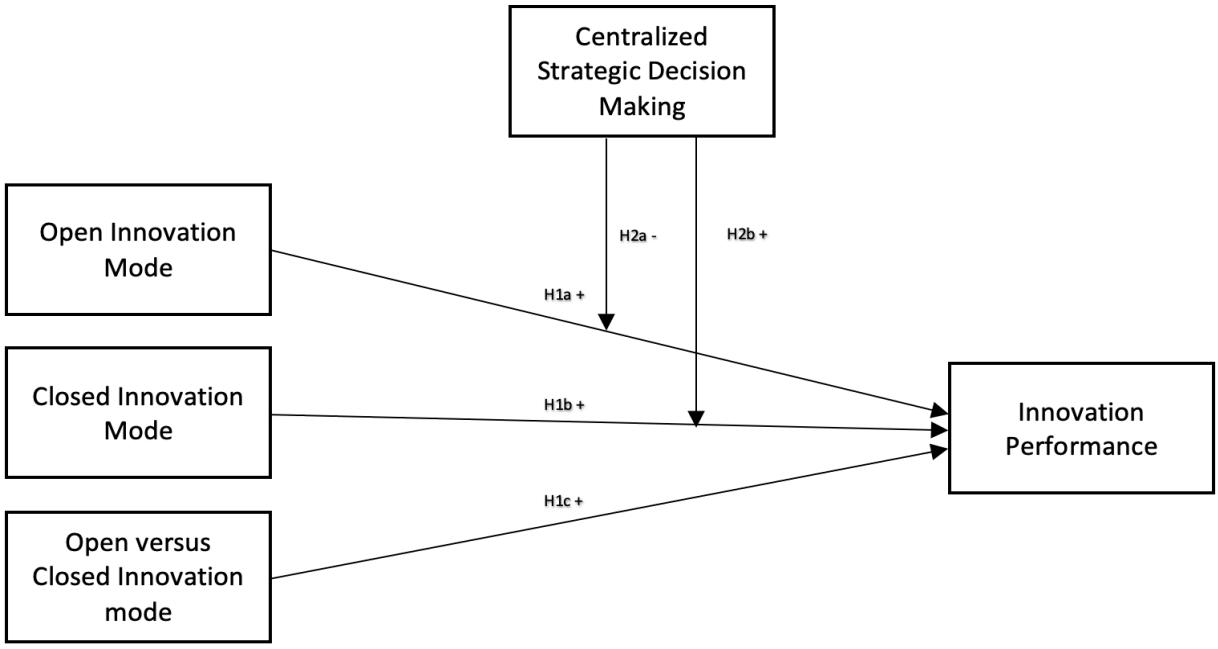

Figure 1: The conceptual framework

3. Research Methodology

In this section, the sample and how the sample is used to measure the hypothesis are discussed. Every variable is explained and aligned with the design of this research. Finally, in the last subsection, the descriptive results are discussed.

3.1 Sample

This study is based on existing data collected by Bruegel from the EFIGE Questionnaire (Altomonte & Aquilante, 2012), also known as the EU-EFIGE/Bruegel-Unicredit dataset. This questionnaire combines measures of an organization's international activities with quantitative and qualitative information about 150 items, including internationalization, financial structures, innovation activities and employees. R&D and innovation are included within these items, therefore fitting with this quantitative study. The survey includes almost 15,000 firms, and the questionnaire was conducted in seven European countries (Austria, France, Germany, Hungary, Italy, Spain, and the United Kingdom). The data were finalized in 2010 and included the years between 2007 and 2009. The EFIGE Questionnaire is based on the firm level, which fits with the level of analysis in this study. Truncated dataset 1 is open and available, and the information is complete, providing a significant dataset for the analysis.

3.2 Research Strategy

In this study, the unit of analysis will be at an organizational level. Other research into open innovation is done at other unit-of-analysis (Ecosystem, individual, project) (Bogers et al., 2017). However, with the chosen variables, analysis at the firm level is the only possibility in this case. The dataset is already focused on a specific group of countries, and in this research, there will be no exclusion based on country type. First, the data are cleaned before analysis of the relationships and descriptive statistics. In the Truncated Dataset 1 in Excel form, missing information will be deleted, as these could potentially influence the results and are not necessary for analysis. After deleting missing variables from the moderating variable (Strategic Decision-Making), the total dataset of 14,770 observations was decreased by 522 observations, as these were missing observations for the moderator. Second, observations missing the key innovation performance indicator of ‘innovation turnover’ were deleted. Out of the 14,238 observations, only 6,861 remained, as 7,377 were missing observations for the innovation turnover. This amount of data is broad enough to find statistical evidence for the hypotheses. Given that Bruegel executed the questionnaire randomly, taking only a fraction of the entire dataset is unnecessary. After the observations are deleted, the leftover dataset is checked for outliers and extreme observations. The data are retrieved over three years but represent a single-point-in-time measurement and cross-sectional data. All the regressions are executed in the statistical software program Stata.

Based on its nature, the variable of innovation turnover (0 to 100 percent) is continuous, and therefore a linear regression will fit. To overcome potential outliers, robust linear regression is used to account for the standard errors. Robust linear regression is an alternative to least square regression and is better for less restrictive assumptions. The potential issue of outliers, in this case, is accounted for, ensuring that the estimated coefficients are not be heavily affected by extreme observations that impact the weight attached to these results (Verardi & Croux, 2009).

In this study, there are three dependent variables: in addition to innovation turnover, the variables of organizational innovation and intellectual property are dichotomous and fitted with either a probit model or linear logistic (logit) regression. As the indicators suggest, the patent application and organizational innovation variable explains the success rate of an organizations innovation activities (yes for a patent and yes for organizational innovation). Probit regression focuses on the likelihood that an outcome falls in a given category, while logit focuses on the chances of success (Kumar, 2022), which means that logit regression aligns better than probit regression with the variables chosen for this study.

3.3 Variables

Multiple variables will be used to gain insight into their effect while controlling for other variables outside the focus of this study. All variables will be explained in this subsection, defining how the constructs (innovation performance, innovation modes, strategic decision-making) are measured in this study.

3.3.1 Dependent variables

In this study, innovation performance is measured in three ways. The first is focused product innovation turnover, This is the level of product sales created by products that are financially beneficial for the organization. In the research of Laursen and Salter (2006), they measure the level of openness by the percentage of turnover created by new or significantly improved products (separate questions). The following question used in the EFIGE Questionnaire regarding innovation turnover differs slightly from that study: *'Indicate the average percentage of turnover from innovative products sales on average in the last three years (2007–2009)'.* If an organization performs well on this scale, its innovation performance will increase by a higher percentage. This variable had to be Winsorized at the 97th percentile because the truncated dataset included extreme observations. This way of measuring innovation performance has been widely used and can therefore indicate innovation performance (Cassiman & Veugelers, 2006; Laursen & Salter, 2006).

Second, we determine innovation performance based on intellectual property innovation performance. This is measured based on whether a company applied for some form of intellectual property (A patent). In this case, the following question of the EFIGE dataset is used: *'on average in the last three years (2007–2009), did your firm ... ? (multiple answers allowed)'* In which the respondent can choose whether they applied for a patent, or register for an industrial design, or for a trademark, or claim copyright. This measurement is focused on patent applications and therefore used as a dichotomous variable: no application for a patent (0) and applied for a patent (1). Through this measurement, it is determined whether open and closed innovation affect the creation of intellectual property and therefore affect product innovation. Patent data has been used in previous research into open innovation and can indicate innovation performance (Chesbrough, 2003).
Third, innovation performance is measured in terms of organizational innovation using the following question: *'Did this product/process innovation also prompt any organizational innovation?'* This question can be answered by no (0) or yes (1).

With the chosen variables, innovation performance is measured in three ways to determine whether the innovation mode impacts this performance. Innovation financially is measured by the innovation turnover, inside process innovation is measured by the effect of innovation on organizational innovations and product innovation is measured by the applications for patents. Broader insight is gained into the effects on innovation performance by measuring innovation performance in many ways (Ciric, Borocki, Gracanin, & Lalic, 2016). This section also addresses the discriminant validity of this study, as the construct of innovation performance construct is measured on multiple levels (product, organizational/process, financial). These three measurements provide a broader view of the effects on innovation performance from multiple perspectives. The measurements all concern innovation performance (Ciric et al., 2016), but their constructs are different.

3.3.2 Independent variables

Open and closed innovation must be constructed as independent variables in this study. There are many ways to analyse open innovation. The research of Laursen and Salter (2006) used 15 separate questions to measure the breadth and depth of openness. In this study, the construct of open and closed innovation focuses primarily on R&D intensity and the balance between open and closed expenditures. First, the following questions are divided into two possible categorical answers: '*If we assume that the total R&D investments equals to 100%, which percentage on average in the last three years (2007–2009) has been ... (ask only if applicable)*'. One category of answers is open intensity, which includes the following possibilities: acquired from external sources in the home country and acquired from external sources abroad. The second category represents closed intensity; this variable indicates the percentage of R&D

expenditures focused on the firm itself (carried out in-house, acquired from another firm in the group in the home country, or acquired from other firms in the group abroad). Combined, these categories indicate the total percentage of open versus closed R&D. Many firms have different levels of total investment in their R&D. To include this variation, the total R&D percentage is multiplied by the percentage of R&D investments over the total turnover. Thus, there is a broad variance in open R&D investments (open R&D intensity) and closed R&D investments (closed R&D intensity), taking into account the firm-specific innovation focus.

Second, the percentage of total open intensity is used to determine the effect of open innovation versus closed innovation. This measurement follows the line of openness, by measuring how open an organization is based on the allocation of the organizations its R&D expenditures. If fully closed intensity, the total openness is 0%, in that case, there is only closed innovation. Therefore, every percentage of the total spent on open innovation represents the percentage of open innovation, with a lower percentage indicating less open innovation expenditures. With this variable, the focus on open versus closed innovation is measure by the level of openness of an organization.

3.3.3 Moderating variable

This study looks at the outer extremes of strategic decision-making to measure how an organization's strategic decision-making is regulated. A company has either a centralized decision-making structure (0) or a decentralized decision-making structure (1) (strategic decision-making). The following question is asked: '*With reference to strategic decisions, which of the following statements better describe your firm situation? Decisions in your firm are ...?'* The respondent can answer in this case centralized or decentralized. Research shows that, in a normal situation, there is a balance between different strategic choices (Rosenzweig, 2013). Previous literature shows that the measurement is based mainly on multiple aspects of the decision-making process, such as differences in strategy formulation and implementation (Elbanna, Thanos, & Jansen, 2020). In this study, this measurement is a dichotomous variable to define simply whether a company makes centralized or decentralized strategic decisions.

3.3.4 Control Variables

To enhance the internal validity of this study, environmental and organizational characteristics can influence innovation performance and, therefore, be included to improve the conceptual framework. This study includes three known influencers of innovation performance that are available in the truncated dataset to control the variables that influence innovation performance. First, innovation performance can be influenced by the organization's size (firm size) (Nobel & Birkinshaw, 1998; Ecker, Van Triest, & Williams, 2013) and will be measured based on the number of employees. Therefore, a firm-size control variable is

included; in the questionnaire, firm size is grouped by Bruegel in the following way: 10–19 employees (1), 20–49 employees (2), 50–249 employees (3), and 250 employees or more (4). Second, the industry is an influential factor in innovation performance (Almirall & Casadesus-Masanell, 2010; Audretsch & Belitski, 2022) (industry). Due to the dataset's restrictions for anonymity, industries are not known but are categorized by numbers. In this study, 11 types of industries are included. Lastly, an influential factor on innovation performance is country of origin (Zhang, Hult, Ketchen, & Calantone, 2020). For this reason, the variable of country is included in this study. In the dataset, the questionnaire was sent to seven EU countries and is therefore focused upon these countries (Austria, France, Germany, Hungary, Italy, Spain, and the UK).

3.4 Descriptive statistics

Basic statistics are analysed in this subsection using the EFIGE truncated dataset to explore how open and closed innovation affect innovation performance. In addition, the way strategic decisions are made is included as a moderating variable. Finally, in Table 1, all the variables are summarized based on the number of observations, the standard deviation, and the minimum and maximum.

There are fewer observations for the independent variables than for the other variables (open and closed R&D intensity). However, these missing observations are left in the dataset, as deleting these observations could lead to deleting total openness of total closed innovation. Furthermore, the variables included extreme observations. Before executing the statistical methods, the extreme observations of the variables were Winsorized at the 99th percentile because extreme observations were found at the extreme right of the normal distribution.

The moderating variable is a dummy variable, and the base variable is centralized strategic decision-making. As shown in Table 1, the mean is not in the middle because fewer decentralized strategic decision-making observations exist. The control variables (industry, firm size, and country) are dummy variables and are controlled for in the statistical analysis, but not included in the descriptive statistics, as these variables are used as dummies.

Lastly, the dependent variable is based on the three variables controlling for firm performance. Organizational innovation and patent variables are both dummy variables. With dummy variables, the options are probit and logit regressions. For patent data, the base variable is that the organization did not apply for patents. For organizational innovation, the base is that the organization had no organizational innovation. For innovation turnover as third dependent variable within this study, there are multiple extreme observations within the truncated dataset, as there are unusual percentages found. Therefore, via

Winsorizing at the 97th percentile at the extreme right, these observations were based on the mean variable. A pairwise correlation check was executed to determine whether there was a case of multicollinearity within this study and whether the independent variables were correlated (see appendix A). Pairwise correlation is below 0.7, suggesting no issue with multicollinearity in this study.

Table 1: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Open R&D Intensity	930	2.916	3.928	0	20
Closed R&D Intensity	1815	6.083	7.58	0	50
Open versus Closed R&D Intensity	1904	19.341	27.946	0	100
Strategic Decision-making	6859	.328	.469	0	1
Patent	6859	.231	.421	0	1
Organizational Innovation	6810	.472	.499	0	1
Innovation Turnover	6859	23.542	25.78	0	100

4. Results

This section presents the statistical outcomes of the analysis and how these results can be interpreted regarding the hypothesis stated in the section '*Theoretical framework and hypothesis*'. First, the purpose of this study will be once again addressed to explain why detailed analyses are done. Second, the analysis will be shown, and the results will be interpreted. Lastly, this section ends with a summary of the results of the hypotheses of this study.

The main purpose of this study is to examine open innovation and its effects on the performance of organizations. This addresses an important topic for organizations that want to gain a competitive advantage via innovation and want to know how to gain this advantage effectively, leading to a sustainable advantage. Therefore, strategic decision-making is used as a construct for organizations to determine whether centralized or decentralized decision-making would produce the greatest benefits for innovation performance given a company's chosen innovation mode. The statistical method is the robust regression model used to exclude outliers from the regression results. The dependent variable of innovation turnover, used as an indicator of innovation performance, is an interval variable, which also fits with linear regressions. For patent and organizational innovation, a logit model is used because the success of these measurements is based on dichotomous variables.

In Table 2, the relationship of the innovation modes and the moderating effect of strategic decision-making with innovation turnover as first dependent variable is shown. The models shown in Table two followed a robust regression, with multiple variables included. All five models following a robust regression were significant overall (Prob > F = .000). Based on the results from the five robust regressions, hypothesis 1a regarding the positive relationship between open innovation and innovation turnover is supported. This result is consistent with the primary hypothesis that open innovation will positively affect innovation performance. When there is a higher open R&D Intensity, the innovation turnover will increase in every model with innovation turnover as the dependent variable. These results show that *hypothesis 1a is strongly accepted*. Second, there is a positive relationship between an closed innovation mode and innovation turnover in every robust regression. This result supports the primary hypothesis 1b, which proposed that closed innovation is positively related to innovation turnover. The results indicate that more closed R&D intensity will lead to higher innovation turnover, and *hypothesis 1b is strongly accepted*. Model 2 shows a negative relationship between the level of openness and innovation turnover, suggesting that a lower percentage of open innovation expenditures lead to higher innovation turnover. This result contradicts hypothesis 1c, which states that the innovation turnover will have a more positive effect when openness is higher. The result is significant and shows that fewer investments in open innovation and more in closed innovation will lead to higher innovation turnover. This outcome means that *hypothesis 1c is rejected*.

Based on the results shown in models 4 and 5, there is no significant moderating effect of decision-making on the relationship between open R&D Intensity and Innovation Turnover. The P-value given is higher than the moderately accepted 0.1 (P-value M4 = .128; P-value M5 = .420). The results show a negative moderating effect of decentralized strategic decision-making, which is not consistent with the primary hypothesis h2a. The hypothesis proposed that the effect of decentralization would positively moderate the relationship. However, since the results are not significant, *hypothesis h2a is rejected*. In models 3 and 5, the results of strategic decision-making as moderating variables for the relationship between closed R&D intensity and innovation turnover are presented. The results *highly support hypothesis 2b*, as decentralized decision-making negatively affects the relationship. The base variable, centralized decision-making, positively moderates the relationship between closed innovation and innovation performance, as stated in the primary hypothesis.

Table 2: Robust regression with innovation turnover as a dependent variable

Model	M1	M2	M3	M4	M5
Dependent Variable Independent Variables	Innovation Turnover	Innovation Turnover	Innovation Turnover	Innovation Turnover	Innovation Turnover
Closed R&D Intensity	.95*** (.09)		1.112*** (.101)	.888*** (.09)	1.079*** (.107)
Open R&D Intensity	.548*** (.177)		.482*** (.177)	.717*** (.202)	.602*** (214)
Strategic Decision-Making	-.788 (1.073)	.163 (.743)	1.711 (1.367)	.134 (1.314)	2.049 (1.414)
Open versus Closed R&D Intensity		-.038*** (.014)			
Decentralization, Closed R&D Intensity			-.626*** (.162)		-.557*** (.192)
Decentralization, Open R&D Intensity				-.479 (.314)	-.3 (.371)
Industry Dummies	Yes	Yes	Yes	Yes	Yes
Firm Size Dummies	Yes	Yes	Yes	Yes	Yes
Country Dummies	Yes	Yes	Yes	Yes	Yes
Observations	840	1904	841	841	840
R-squared	.258	.054	.262	.245	.262

Standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

In Table 3, the relationship with patent applications is shown. In these five analyses, a logit regression was used. All the models had an overall significance below.05 and are therefore statistically significant. Open R&D intensity and the results from Table 3 show that this type of R&D intensity negatively affects the odd ratio of the patent application. However, this effect is close to zero. There is no significant effect in all models, which led to a *rejection of hypothesis 1a*. Models 6, 8, 9, and 10 show that hypothesis 1b, that closed innovation is positively related to innovation performance, is accepted (when the patent application is used). Therefore, *hypothesis 1b is strongly supported* in the case of more patent applications. *Hypothesis 1c is rejected*, as this result is not significantly different from zero. The smaller the open R&D intensity, the better these results are since the coefficient is negative. Nevertheless, this result is not significant, so this effect cannot be concluded. The results of models 8, 9, and 10 led to the *rejection of hypotheses 2a and 2b*, as the results are insignificant. There is no supporting evidence that centralized or decentralized strategic decision-making positively moderates the relationship.

Table 3: Logit regression with patent application as a dependent variable

Model	M6	M7	M8	M9	M10
Dependent Variable Independent Variable	Patent Application	Patent Application	Patent Application	Patent Application	Patent Application
Closed R&D Intensity	.057*** (.014)		.059*** (.016)	.056*** (.014)	.059*** (.017)
Open R&D Intensity	-.012 (.027)		-.013 (.027)	-.01 (.031)	-.014 (.033)
Strategic Decision-making	.144 (.162)	.149 (.113)	.193 (.211)	.16 (.2)	.19 (.219)
Open versus Closed R&D Intensity		-.002 (.002)			
Decentralization, Closed R&D Intensity			-.009 (.025)		-.01 (.029)
Decentralization, Open R&D Intensity				-.006 (.049)	.003 (.057)
Industry Dummies	Yes	Yes	Yes	Yes	Yes
Firm Size Dummies	Yes	Yes	Yes	Yes	Yes
Country Dummies	Yes	Yes	Yes	Yes	Yes
Observations	840	1904	840	840	840
Pseudo R^2	.108	.094	.109	.108	.109

Standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

In Table 4, the results from the logit regression for organizational innovation are summarized. In general, the five models are moderately significant. The Chi-Square test results are not strongly significant, based on the .05 significance level. The models are generally between .05 and .1. According to these results, hypothesis 1a is rejected, as there is insufficient evidence that open R&D intensity positively affects organizational innovation. Second, hypothesis 1b is rejected, as there is no significant positive relationship between closed R&D intensity and organizational innovation. The results shown in all models demonstrate a positive effect, but this cannot be confirmed statistically. The third hypothesis, 1c, is rejected because no significant effect is shown in model 12 (M12). Hypothesis 1c expects that open innovation will have a higher positive effect on innovation performance than closed innovation. The negative results suggest that closed innovation is more effective, but this cannot be supported by statistical significance, and the effect is close to zero (-.001). In model 12, decision-making has a significant result directly on organizational innovation. This effect is positive, suggesting that decentralized decision-making is positively related to organizational innovation.

Hypothesis 2a is rejected, as there are no significant results for the moderating effect of decision-making on the relationship between open innovation and organizational innovation. In models 14 and 15, no significant result is shown. The coefficient is negative and close to zero, suggesting that centralized decision-making is more effective, yet this is insignificant and cannot be concluded. Hypothesis 2b is rejected because there is no significant effect. The results suggest that decentralized decision-making combined with a closed innovation mode is more positively related to organizational innovation, but the data in this study cannot support this effect.

Table 4: Logit regression with organizational innovation as a dependent variable

Model	M11	M12	M13	M14	M15
Dependent Variable Independent Variable	Organizational Innovation	Organizational Innovation	Organizational Innovation	Organizational Innovation	Organizational Innovation
Closed R&D Intensity	.021 (.013)		.021 (.015)	.021 (.014)	.019 (.016)
Open R&D Intensity	.027 (.026)		.027 (.026)	.033 (.03)	.035 (.031)
Strategic Decision-making	.247 (.153)	.268*** (.104)	.247 (.199)	.293 (.188)	.273 (.206)
Open versus Closed R&D Intensity		-.001 (.002)			
Decentralization, Closed R&D Intensity			0 (.025)		.007 (.029)

Decentralization, Open R&D Intensity				-.02 (.047)	-.026 (.054)
Industry Dummies	Yes	Yes	Yes	Yes	Yes
Firm Size Dummies	Yes	Yes	Yes	Yes	Yes
Country Dummies	Yes	Yes	Yes	Yes	Yes
Observations	830	1888	830	830	830
Pseudo R^2	.028	.024	.028	.028	.028

Standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

Generally, all fifteen models are supported. Only models 11 to 15 are moderately significant. Models 1 to 10 are highly significant, with a significance of .000. The results on the individual effects imply that multiple hypotheses are partially accepted based upon the three indicators for innovation performance. It can be concluded from the results that hypothesis 1a is supported only by the regressions on innovation turnover. The logit regression did not find any significant effect of open R&D intensity on innovation performance in the other models. Therefore, *hypothesis 1a is partially supported*. The second hypothesis, *hypothesis 1b, is partially supported* by two regressions, using innovation turnover as the dependent variable and patent innovation as the dependent variable. No significant effect is shown in the regression using organizational innovation as a dependent variable. Hypothesis 1b is therefore partially supported. The last hypothesis, based on the direct effect between innovation mode and innovation performance, *hypothesis 1c, is not supported in any regression*. In Table 2, only the regression based on innovation turnover shows a significant effect. However, h0 is supported in the results, as the result is negatively significant. This result shows that closed innovation has a more positive effect on innovation turnover. This outcome is the opposite of the expected effect, and therefore *hypothesis 1c is rejected*.

The second part, focused on the interaction between the innovation mode and strategic decision-making, shows that *hypothesis 2a is not supported*. There is no significant moderating effect of strategic decision-making on the relationship between open innovation mode and innovation performance in all the models. However, *hypothesis 2b is partially supported*, based on the results in Table 2 (innovation turnover). A significant effect shows that centralized decision-making positively impacts the relationship between a closed innovation mode and innovation turnover. The innovation mode affects primarily the innovation turnover, while other performance indicators for innovation show no significance.

5. Conclusions and recommendations

In this section, the findings are discussed and the results are interpreted. Furthermore, valuable implications of the research findings are suggested. Finally, in the second sub-section, the limitations encountered during this research are recognized and leading recommendations for future research are given. This section will end with a conclusion from the research results.

5.1 Interpretation and implications

This research aims to determine which innovation mode leads to higher innovation performance and how strategic decision-making affects this relationship between innovation mode and innovation performance. Many studies have shown alignments and contradictions within the field of open innovation on firm and innovation performance (Bae & Chang, 2012; Ili et al., 2010; Inauen & Schenker-Wicki, 2011; Audretsch & Belitski, 2022; Abhari & McGuckin, 2022; Lichtenthaler et al., 2011). Therefore, this study aims to learn how organizations can increase their innovation effectiveness via specific innovation modes and types of strategic decision-making. The results show different effects for each innovation performance indicator, mainly positive effects and higher importance for closed innovation than open innovation. This contradicts the findings of Bae and Chang (2012). Furthermore, centralized decision-making in a closed innovation context is proven to be more effective for innovation turnover.

Multiple indicators are used to analyse whether innovation performance is positively affected by the innovation mode. There are no similar effects on the indicator, as organizational innovation do not show significant signs of a positive relationship, while innovation turnover and patent applications do. In an open innovation mode, this can be influenced by the organization's culture (Herzog, 2011), decreasing the effectiveness of open innovation. In particular, the effect of organizational innovation performance can be influenced, as an open innovation mode has many consequences for managers, the organization, and collaborations (Lichtenthaler et al., 2011). In a closed innovation mode, the organizational innovation performance does not increase significantly. This effect might be because the process of closed innovation follows three clear steps and becomes standardized to achieve the rate of innovative products (Herzog, 2011). There is a positive relationship between closed innovation and the number of companies that apply for a patent. This result aligns with the expected result, one reason is that closed innovation companies have a tendency to achieve 'first mover advantage' (Herzog, 2011) and therefore apply earlier for patents. Also, these companies try to have the best personnel in house, which might increase the pace at which closed innovators apply for patents. However, examining open innovators, one reason for lower innovation performance in an open innovation mode is that one company takes all control within open innovation co-

governance (Lichtenthaler et al., 2011), as the engagement mechanisms may not be strong enough to exploit open innovation and knowledge for all the firms thoroughly.
On the one hand, based on innovation turnover as an indicator, significant results show that both closed and open innovation have a higher positive impact on performance when there is more investment in innovation. In an open innovation mode, organizations can benefit from the value that partnerships, acquisitions, and other investments offer to increase organizational knowledge (Chesbrough, 2003; Chesbrough, Haverbeke, & West, 2006; Inauen & Schenker-Wicki, 2011). On the other hand, closed innovation also positively affects the relationship between innovation mode and performance, and a closed innovation mode focuses on creating new products first (Herzog, 2011). Therefore, it may be possible that the results of patent innovation performance and innovation turnover, both of which are significantly positive, are affected by a focus on innovation.

A contradictory result is that organizations with lower openness, and therefore higher closed innovation expenditures, are more likely to have a higher positive innovation turnover, which means that the balance between both innovation modes is better focused on internal innovation. One reason for this result may be that, due to the current internationalization, which is shown to have a negative influence, open innovation ecosystems are not functioning as well as expected and are declining the effectiveness (Audretsch & Belitski, 2020). Another negative influencer of higher openness on the relationship with innovation turnover is the establishment of adequately managed co-governance, as shown by the study of Lichtenthaler et al. (2011). Overall, the present study seeks positive linear relationships. However, as known from other studies (Laursen & Salter, 2006), openness can be balanced with closed innovation, so there could be an optimum level of open innovation expenditure.

Based on the first part of the results focusing on the direct relationship between innovation modes and innovation performance, no one exact conclusion can be drawn. Regarding the balance between open and closed innovation, there are indications that firms could better balance their expenditures, focusing on closed innovation. There is no one innovation mode that necessarily improves different innovation performance indicators. Higher innovation activities (either open or closed) are positively related to innovation turnover.

In the second part of the results, the focus is on the moderating effect of strategic decision-making on the relationship between the innovation modes and performance. No overall conclusion can be extracted from the statistical analysis. With innovation turnover, it is accepted that closed innovation combined with a centralized decision-making structure has the most positive impact on performance. Based on the literature

in combination with this study's findings, this impact is related to the opportunity-seeking focus known to be associated with centralized decision-making authority (Mintzberg, 1973; Carter, 1971). Another reason for these results may be the increased decision-making speed of in case of trends in the market (Baum & Wally, 2003). From the open innovation perspective, no significant results are found, so it cannot be concluded that decentralization is more effective in the open innovation mode.

5.2 Limitations and future research

During the progress of this study, multiple construct issues were identified by way of data collection. Primary data collection could have been done for this study via a survey. Surveys are easy to administer, can be developed within a short period, and can collect a broad range of data (Fowler, 2014). In addition, the survey questions could have been created specifically regarding the necessary variables. However, given the time constraints of this research, quickly available secondary data was necessary to conduct this study. This type of research is generally done by surveys or existing data. In some cases, researchers use data analytics to find words concerning open innovation in stakeholders' letters (Bogers et al., 2016), but that would be too time-intensive and resource-intensive, and obtaining variable measurements would be difficult. The data collection constraint also resulted in issues with the constructs used for the variables. As the theoretical background of open innovation has shown, open innovation is not a construct used only with open and closed R&D expenditures. Moreover, studies follow a breadth and depth of open innovation (Laursen & Salter, 2006), with some studies following constructs that focus on acquisition and exploration (ETA and ETE) (Hung & Chou, 2013). Lastly, studies measure open innovation by the inbound and outbound focuses of the organization (Parida, V., Westerberg, M., & Frishammar, J, 2013; West & Bogers, 2014). It was not possible to use these three options for measuring open innovation due to the anonymized dataset from the secondary source.

Concerning the ways of measuring the dependent variable, patent applications do not show the added value that organizations extract from their innovation actions. In other studies, patent applications are used as a count variable to indicate innovation performance, with consideration of the number of applications an organization has made over time (Chesbrough, 2003). However, due to the anonymization of the observations, it was impossible to know the company and its number of patent applications. Therefore, the dummy variable was used. Furthermore, the construct for organizational innovation performance does not have enough depth to measure improvements to that type of innovation performance. There are many different ways to measure organizational innovation performance more specifically, for example at product level (amount of patent, new products, improved products), employee level (innovative ideas generated by employees) (Ciric et al., 2016).

Lastly, during this study, the choice for centralized and decentralized strategic decision-making could differ per type of decision (Rosenzweig, 2013), which means that any given way of measuring strategic decisions is not directly applicable to all the decisions that a company makes. As shown by other research, strategic decision making and the way of controlling also differs among departments (Siggelkow & Rivkin, 2006) or is different by subsidiaries of an MNE (Beugelsdijk & Jindra, 2018).

Based on the limitations, interpretations, and implications of this research, there are many interesting ways to explore the field of open innovation further. Regarding the limitations, future studies could use surveys or interviews to gain in-depth information of all the specific variables in this study. Via surveys, future studies could scale strategic decision-making and divide it into multiple types of decisions – the same applies to open innovation, with the development of a focused way of explaining whether a company is open. Furthermore, this study focused on seven European countries, while decision-making and open innovation are affected by cultural differences (Herzog, 2011); it is thus recommended to broaden the scope to more (non-EU) countries.

Following the implications of this study, further research could investigate the effects of different types of strategic decisions on the relationship between innovation mode and performance. In most cases, strategic decisions differ not only by the way executives divide their authority but depend on situations and types of decisions (Rosenzweig, 2013). Another interesting topic is the balance between open and closed R&D expenditures and the optimum balance between them in specific industries (Almirall & Casadesus-Masanell, 2010) or firm sizes. The results regarding strategic decision-making suggest that centralized decision-making is more effective but that this effect could diminish over time. On the other hand, this effect might be overstated, as this study uses cross-sectional data. In the future, the same study could be conducted with panel data to determine whether this effect is also significant over a more extended period. Lastly, based on the interpretation of the results, future studies could focus on this type of relationship at different levels of analysis. Particularly at the project level, open innovation is an interesting field, especially when combined with decision-making strategies and the interference of top management in innovation performance. In addition, looking at specific individual characteristics of leaders in open innovation could be interesting for the eventual outcome of innovations.

Concluding the results of this study, it is shown that both open and closed innovation have advantages for increased innovation performance. However, comparing the level of openness in innovation, it can be recognized that innovation turnover is higher with less openness, which is a relatively different result compared to other open innovation studies. In addition, organizations' strategic decision-making in a closed context is better when having centralized strategic decision-making.

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Appendix

Appendix A: Pairwise correlation between independent variables

Pairwise Correlation between independent variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Open R&D Intensity	1.000						
(2) Closed R&D Intensity	0.557	1.000					
(3) Open versus Closed R&D Intensity	0.470	-0.129	1.000				
(4) Strategic Decision Making	-0.120	-0.049	0.013	1.000			
(5) Industry	-0.014	-0.047	-0.009	0.005	1.000		
(6) Firm Size	-0.200	-0.121	-0.093	0.176	0.039	1.000	
(7) Country	0.063	-0.022	0.368	0.073	0.036	-0.094	1.000