

## NECESSARY AND SUFFICIENT ANTECEDENTS OF ADOPTING OPEN INNOVATIONS IN INDIA'S MANUFACTURING SECTOR: NCA AND FSQCA APPROACH

Puneet Gupta<sup>1</sup>, Vinita Choudhary<sup>1</sup>

<sup>1</sup>*School of Leadership and Management, Manav Rachna International Institute of Research & Studies Sector-43, Surajkund-Delhi Road, Faridabad- 121004, India*

### Abstract

Open innovation is gaining recognition as a strategic approach for the industrial sector to enhance competitiveness and adaptability. This study investigates the primary determinants influencing the implementation of open innovation (OI) in Indian manufacturing firms, a context that is presently insufficiently addressed in the existing literature. Innovation theory and the resource-based view, seven antecedents are examined: competitive advantage, government support and policy, innovation and flexibility, knowledge absorptive capacity, market uncertainty, organizational readiness, and proactivity. This study aims to determine the factors that influence Indian manufacturing companies' decision to adopt open innovation, including organizational readiness, competitive advantage, government policy and support, innovation and flexibility, knowledge absorption capacity, market uncertainty, and proactiveness. The study employed a descriptive and causal design and used primary data gathered from 398 senior executives in the manufacturing sector. We used a structured questionnaire that was based on items that had been validated in previous research to gather data. The proposed hypotheses were tested and the significance of the correlations between the constructs was evaluated using Structural Equation Modeling via Partial Least Squares (SEM-PLS). The results show that organizational readiness, competitive advantage, innovation and flexibility, market uncertainty, and proactiveness all have a major impact on OI adoption. Organizational readiness was more important than government support or the capacity to take in new information. These results show that internal strategic and structural capabilities of Indian businesses are more significant in promoting OI practices than external institutional support. This work adds to the theory of innovation in emerging economies by providing a tested structural model that can be applied to the manufacturing sector in India. It illustrates that lawmakers need to change the way they aid businesses and that businesses need to use their own skills. The study shows that innovation methods that work in one place may not work in another, especially in economies with limited resources and different types of institutions.

### 1. Introduction

Innovation is absolutely necessary if the global industrial environment is to continue to experience competitiveness, efficiency, and sustainability. Research and development carried out within the company has, nevertheless, always been an essential component of industrial innovation frameworks. The exchange of information between different departments has grown more difficult as a result of this (Szromek & Bugdol, 2024). As the velocity of change in both markets and technology continues to accelerate at a dizzying rate, the limitations of these restrictive techniques of idea development are becoming increasingly apparent. Over the course of the past several years, the idea of "Open Innovation" (OI) has generated a lot of enthusiasm. Through the use of Open Innovation, entities such as enterprises, customers, suppliers, universities, startups, and even competitors have the opportunity to collaborate on the development of novel ideas and discoveries (Fu et al., 2022). Through the utilization of more flexible production processes that are made possible by OI, manufacturers are able to generate new goods, reduce the expenses associated with innovation, and adapt to Industry 4.0, the Internet of Things, and sophisticated analytics, as stated by Yang et al. (2021). Infrastructure, human capital, and money are three areas in which developing countries like India face challenges. In addition to these worries, Cordeiro et al. (2022) acknowledge that the possible inclusion of OI into global innovation networks is something that should be taken into consideration. Despite the fact that it has a great deal of promise, the manufacturing industry in India has had a diverse response to the implementation of operational innovation. Since many companies are still using antiquated methods of R&D, it is essential to know the pros

and cons of open innovation (Chatterjee et al., 2021). To identify these components, it is necessary to employ methodological frameworks capable of uncovering both the essential conditions for adoption and the combinations of characteristics that can independently promote adoption, referred to as adequate configurations. Fuzzy-set Qualitative Comparative Analysis (FsQCA) and Necessary Condition Analysis (NCA) provide further insights. The primary objective of NCA is to identify the non-compensatory limiting conditions essential for the feasibility of the outcome (OI adoption). Adoption cannot occur in the absence of a prerequisite, irrespective of the quality of all other aspects. But FsQCA highlights causal complexity by identifying various permutations of conditions sufficient to produce the result. It recognizes that different people may adopt in various ways and that different circumstances can have similar effects in different situations. This study integrates the two methods to identify the components that must be present for OI adoption and the combinations of components that can bring about its adoption. Policymakers, managers, and stakeholders in India's manufacturing industry can gain actionable insights from this dual perspective, which helps them understand the adoption process better in line with national efforts like Make in India plan.

The implementation of OI in Indian manufacturing firms and delineates the obstacles to its broader adoption. This study suggests that organizational preparation, innovation and flexibility, competitive advantage, market unpredictability, and proactivity may influence the adoption of open innovation. Each antecedent functions as an independent variable within the analytical framework, encompassing an organization's internal resources, strategic position, and external environment (Qu & Kim, 2024). The endogenous construct of OI adoption indicates the degree to which firms incorporate open innovation principles into their operations. Previous research often evaluated the statistical significance of these interactions using one-dimensional approaches, such as regression and Structural Equation Modeling (SEM). The reliability of the measurement model and its proposed antecedent relationships are evaluated through PLS-SEM (Wang et al., 2022). Statistical significance does not establish that a component is essential for OI adoption, nor does it consider alternative pathways for adoption. This study employs NCA and FsQCA to address this gap, utilizing two independent but interrelated methodologies. NCA is used to find non-compensatory bottlenecks, which are the lowest values of an antecedent that must be met for OI adoption to happen. This answers the question: "Which conditions are absolutely essential for adoption, regardless of other factors?" In contrast, FsQCA identifies causal configurations different combinations of antecedents that are sufficient to produce high levels of OI adoption. This study examines the question: "What combinations of conditions facilitate adoption, and how can different firms attain it through various pathways?" This study integrates NCA and FsQCA with SEM-PLS, providing a comprehensive perspective that connects statistical association, necessity, and sufficiency. This tri-method approach offers a strong empirical basis for analyzing the interplay of organizational, strategic, and environmental factors affecting OI adoption in the manufacturing sector. The results will guide decision-making within the organization by assisting leaders in identifying key capabilities, understanding flexible adoption routes, and aligning strategies with the specific context. The findings will aid policymakers in developing supportive frameworks, especially regarding national initiatives like Make in India and the Production- Linked Incentive (PLI) scheme, to cultivate an environment conducive to innovation in developing economies such as India.

This research investigates open innovation within India's industrial sector, an essential yet underexplored subject. Extensive research on OI exists in industrialized countries; however, there is a paucity of studies from developing nations due to insufficient infrastructure, institutional support, and organizational growth (Szromek & Bugdol, 2022). Despite initiatives like the Atal Innovation Mission and the National Innovation Council, numerous Indian businesses still face challenges in executing innovative concepts. This study will conduct an empirical analysis of a structural model based on innovation theory and knowledge management frameworks to examine the overall knowledge gap revealed by the implementation gap (Liu, 2023). Investigating the adoption of open innovation through internal and external factors is essential. The preparedness and proactiveness of a company are the most critical factors. Cepeda-Carrion et al. (2022b) indicate that the regulatory framework, competitive market dynamics, and market instability influence the feasibility and rate of adoption. The resource-based view (RBV) asserts that innovation, particularly proactive orientation and competitive advantage, is influenced by strategic resources and organizational behavior. This study illustrates the effectiveness of multi-method approaches utilizing NCA, FsQCA, and PLS-SEM. To determine the extent to which antecedent factors on open innovation adoption exist, PLS-SEM can be employed. The constraints of non-compensatory adoption are the main emphasis of NCA. Despite not optimizing all circumstances, FsQCA identifies many adequate paths with diverse combinations of conditions that may lead to high OI adoption. This comparative methodological design provides more comprehensive and practical insights. It highlights the fundamental conditions that practitioners must create and the various strategic options accessible to them, depending on their context and resources. The findings provide policymakers with insights for developing targeted interventions, including capacity-building programs, sector-specific innovation incentives, and collaborative platforms, to tackle industry-specific challenges (Marzi et al., 2023). This study enhances academic literature and practical knowledge by integrating various perspectives, offering a validated framework for understanding and promoting OI adoption within India's complex and dynamic manufacturing sector (Najib et al., 2021a).

This research report consists of five primary sections, each systematically developing from the preceding one to provide a coherent and thorough analysis. Section 1 outlines the research setting, defines the study objectives, and examines the importance of open innovation in the industrial sector, specifically within the Indian framework. To put OI into action, you need to look at the necessary and sufficient requirements. Section 2 examines studies on OI within several global enterprises engaged in emerging sectors. This text discusses concepts from innovation theory, resource-based strategy, and knowledge management. This study identifies literature gaps and presents a conceptual framework with research hypotheses from previous studies. In the section 3, the design of the study, the sampling strategy, and the data collection are discussed. In this study, we use PLS-SEM, NCA, and FsQCA as statistical tools to examine potential causal pathways and non-compensatory bottlenecks. The statistical and configurational methodologies we employ establish the basis for assessing the reliability and validity of the measurement model. The report we have compiled offers an in-depth analysis of our collective endeavors. This section of the empirical findings details the results of the hypothesis tests, descriptive statistics, and metrics employed to evaluate the model's fit. The second section of the article encapsulates the key points discussed in the first section. This section systematically examines all previous findings, including the results of the hypothesis testing. The findings encompass the outcomes derived from the PLS-SEM analysis, the NCA, and the FsQCA. The incorporation of these essential components can enhance opportunities

for unrestricted creative expression. To enhance understanding, tables and diagrams of the structural model are included. In Section 5, we examine the existing literature and analyze the key findings in relation to the research objectives. The discussion includes potential advantages for management derived from these findings. The report highlights its limitations while proposing potential areas for further exploration regarding the benefits of open innovation for the industrial sector in India.

## **2. Literature Review**

### **2.1 Theoretical background**

Utilizing technical resources, promoting information exchange, and collaborating with other entities can enhance business competitiveness in their respective fields (Abdullah & Almaqtari, 2024). Making value and coming up with new ideas are now much easier thanks to these tactics. Making value and coming up with new ideas are now much easier thanks to these tactics. Combining academic hypotheses with real-world data from previous research, this study examines what motivates companies to embrace open innovation. In terms of open innovation ambitions, India is faced with a number of challenges as well as opportunities. The outcomes are a consequence of the fact that the regulations imposed by the government are in a state of constant flux, in addition to the influence of globalization and the development of technology. The significance of open innovation as a strategic approach for enterprises is increasingly recognized. This facilitates the integration of individual knowledge with external sources, thereby enhancing ideation, reducing time-to-market, and increasing competitiveness (Priyadarshini et al., 2024). Organizations can enhance their innovation outcomes and adaptability in a constantly evolving global environment by leveraging their individual and collective capabilities. Nonetheless, a lack of consistency persists in the implementation of OI within Indian manufacturing firms. Research in developed economies highlights the importance of factors such as network strength, absorptive capacity, and leadership commitment in facilitating open innovation; however, empirical evidence regarding India is limited. Unlike other innovation models, it emphasizes collaboration, knowledge co-creation, and partnership development (Szromek & Bugdol, 2024). Potential benefits encompass enhanced strategic flexibility, cost reduction, and superior innovation performance, which are especially advantageous in volatile and uncertain markets. It is essential to understand the necessary and sufficient antecedents of OI adoption in the Indian manufacturing sector for academic inquiry and practical decision-making.

This research conducts a comprehensive literature analysis to evaluate the strategic implications of open innovation (OI) and identify the variables that influence its adoption within the industrial sector. The Resource-Based View (RBV) functions as a critical theoretical framework within the domain of OI research. The Resource-Based View (RBV) suggests that firms aim to enhance their internal resources via external collaborations to achieve sustained competitive advantage (Naseer et al., 2020). In this context, OI is considered a means of broadening resource boundaries and improving dynamic capabilities. Although the Resource-Based View (RBV) prevails in the literature on Open Innovation (OI), alternative frameworks like Institutional Theory and Transaction Cost Economics (TCE) have garnered relatively less focus. Institutional Theory emphasizes the influence of normative, coercive, and mimetic pressures on the adoption of innovations. In contrast, Transaction Cost Economics (TCE) analyzes the costs related to knowledge exchange, alliance formation, and coordination, and how these costs affect innovation strategies. Examining these perspectives enhances the

understanding of the intricate factors influencing OI adoption across various sectors. This research enhances the literature on open innovation by integrating various theoretical perspectives with empirical data, situating its adoption within the distinct dynamics of India's manufacturing economy. This dual-method approach integrates Necessary Condition Analysis (NCA) and Fuzzy-set Qualitative Comparative Analysis (FsQCA) to identify essential and configurational factors that influence OI adoption.

## **2.2 Organizational Factors**

The effectiveness of innovation activities is greatly affected by a company's absorptive capacity, defined as its ability to acquire, interpret, and apply information from external sources (Fu et al. 2024). Larger companies often possess greater resources, an extensive network of contacts, and advanced technology to support their open innovation initiatives. To address these challenges, it is essential to remain agile, concentrate on specific domains, and establish connections. Integrated systems facilitate communication among individuals across various departments, enabling information sharing and the exploration of innovative approaches. The significance of organizational structure in the context of open innovation is paramount. Innovation necessitates a commitment from leadership towards learning, creativity, and the sharing of resources (Tsai et al. 2022). Inadequate communication, isolated departments, and restrictive organizational frameworks may hinder the implementation of operational intelligence. Establishing a culture that emphasizes cooperation, transparency, and data-driven decision-making is an effective approach to addressing these challenges. Upon the implementation of this data format, the organization can enhance its ability to utilize both internal and external sources to optimize its value chain. Effective organizational preparation and robust leadership support are essential components for facilitating open innovation within the industry.

## **2.3 Technological Factors**

OI necessitates cutting-edge technology to enhance collaboration, facilitate knowledge exchange, and optimize data sharing. A minimum level of technological readiness, including infrastructure, digital tools, and effective Intellectual Property Management (IPM), is often required for firms to participate in OI activities (Haylemariam et al., 2024b). Without this baseline capability, excellent leadership or good market circumstances may not lead to open innovation adoption. The adoption of Industry 4.0 technologies, including automation, smart manufacturing, and advanced supply chain integration, enhances readiness by improving operational efficiency and the potential for external collaboration. Digital technologies such as artificial intelligence, big data analytics, cloud computing, and the Internet of Things (IoT) enhance a firm's absorptive capacity, facilitating the effective processing and application of external insights (Quesado & Silva, 2021a). Strong research and development capabilities, along with digital platforms, enable collaboration with entrepreneurs, universities, and industrial networks, which may contribute to various sufficient configurations for open innovation adoption, as indicated by FsQCA analysis. However, technological obstacles—including inadequate infrastructure, high implementation costs, and cybersecurity risks—can prevent firms from reaching the necessary thresholds for OI participation. To address these barriers, organizations must invest in digital transformation, strengthen absorptive capacity, and develop resilient technological ecosystems. In configurational terms, technological readiness often interacts with factors such as leadership commitment, organizational flexibility, and external networks to form effective pathways toward successful OI adoption.

## 2.4 External Factors

Operational intelligence is becoming crucial for companies aiming to adapt to changing customer demands and sustain a competitive edge. Collaborations with universities, research institutions, and industry networks allow firms to obtain new knowledge, access specialized skills, and generate innovative ideas—essential components that can contribute to adequate configurations for open innovation adoption (Najib et al., 2021a; Mishra, 2024). NCA should team up with universities, entrepreneurs, and businesses to boost open innovation. Collaboration across global markets is essential for contemporary businesses, particularly in light of the rapid evolution of technology and shifting consumer demands. The objectives of open innovation within the framework of FsQCA encompass robust collaboration between public and private sectors, global engagement in value chains, effective management of intellectual property, and the establishment of digital network architecture (Marzi et al., 2023). Skepticism, cultural differences, and intellectual property infringement can restrict the operational collaboration of open innovation. It is essential to implement strategies, establish partnerships, and foster collaboration to enable companies to fully leverage the benefits of open innovation. NCA argues operational intelligence needs these skills. FsQCA integrates technical preparedness, absorptive ability, and leadership commitment to foster innovation, information sharing, and sustainable competitive advantage.

## 2.5 Financial Performance

Research indicates a positive correlation between open innovation (OI) and corporate profitability, with firms leveraging external information typically experiencing lower R&D costs and enhanced productivity (Akjou & Fakhreddine, 2024c). Open innovation typically accelerates product launch timelines, resulting in enhanced and diverse revenue streams. From an NCA perspective, a basic level of financial capacity is crucial for OI, as it directly affects a company's ability to invest in partnerships, innovative technologies, and collaborative research initiatives. In the context of FsQCA, financial strength is frequently identified as a necessary condition for the successful adoption of open innovation, typically alongside high absorptive capacity, leadership commitment, and technological readiness. Profitability enables companies to collaborate, utilize external solutions, and allocate internal R&D resources towards enhancing existing technologies rather than developing new ones (Chen et al., 2024b). Companies that work together internationally can use ideas and tools from around the world, which saves them money. Using outside information lowers the cost of development, speeds up product launches, and makes a business more competitive in the market. To make open innovation work better, you need to be good with money and make sure that technology and businesses work together.

One interesting aspect of OI is its ability to effectively reduce the impact of diversifying risk. When companies join forces with others in their industry, they can share the costs and risks of developing new products and processes, which increases their chances of hitting it big in the market (Ahmed et al., 2024b). OI platforms and crowdsourcing are great, budget-friendly ways to tackle tricky problems. Plus, licensing deals and co-development partnerships help companies tap into better ideas and tech without breaking the bank. These methods keep experimentation costs down and reduce the fallout from any potential flops. In some cases, firms can generate additional revenue by licensing unused intellectual property to external partners. From a NCA perspective, a minimum level of financial risk tolerance and governance capability may be indispensable for sustaining OI partnerships, as these enable firms to manage

contractual complexities, safeguard intellectual property, and align collaborations with strategic goals (Petruzzelli et al., 2021d). Without these abilities, firms may struggle to form open innovation partnerships. FsQCA indicates that effective financial management typically aligns with being technically equipped, having the capacity to acquire new insights, and maintaining robust external connections. These elements combine to create an awesome environment for success driven by open innovation (Radicic & Alkaraan, 2022b). Investing in open innovation is a smart move that can definitely help lower costs and minimize risks. Also, it enhances relationship management, providing companies with a solid advantage over their competitors. Finance management is essential for OI's resource efficiency and creativity.

## **2.6 Innovation Performance**

The integration of diverse external information sources enhances creativity and patent activity in firms engaged in open innovation (Liu, 2023). Collaboration with universities, research institutions, startups, and industry groups significantly enhances product and process innovation, allowing a company to create and apply novel solutions (Cepeda-Carrion et al., 2022b). Innovative unconventional approaches may require intensive external collaboration. From a NCA perspective Organizations may struggle to produce innovative concepts with the same speed or effectiveness in the absence of diverse data types. Innovation flourishes in environments where individuals possess expertise, leadership is committed, external relationships are robust, and new knowledge is rapidly assimilated. FsQCA reveals that agreements provide organizations with access to advanced research, data, and technology. The concept of open invention serves to expedite the process of innovation. OI unlike closed invention, utilizes the expertise of partners to expedite the time-to-market (Ayinaddis, 2023b). Agile organizations are likely to more effectively address consumer and market needs, thereby fostering innovation and enhancing operational processes. Diversity of knowledge significantly contributes to the improvement of innovative results. By collaborating with external stakeholders, firms can include novel perspectives, unorthodox concepts, and interdisciplinary knowledge into their innovation strategy (Singh et al., 2019b). This wide range of feedback leads to new ideas that would not have been conceivable with only an internal research and development team. Open innovation makes it easier for enterprises to share technology, which means they may use and change current solutions instead of developing new ones from start.

Sarpong et al. (2024) indicate that open innovation promotes innovative thinking while presenting challenges related to intellectual property management, the formation of collaborative institutions, and partner trust. Organizations require robust governance, clear contracts, and effective information management systems to ensure mutual benefit. NCA fosters the development of essential organizational and managerial competencies to enable sustainable open innovation and reduce risk. In their absence, technologically advanced or wealthy companies may struggle to connect. The FsQCA found that absorptive capacity, leadership commitment, technology readiness, and organizational preparedness drove open innovation. Open innovation allows organizations to expand, enhance agility, and reduce collaborative risks. Wang et al. (2022) indicate that organizations that succeed in the current market are those capable of rapid adaptation, fostering robust partnerships, and demonstrating flexibility. Through the efficient alignment of strategic, relational, and technological resources with key planning criteria, organizational intelligence supports organizations in sustaining a competitive edge.

This study develops a conceptual framework grounded in the theoretical underpinnings of innovation management and the resource-based view (RBV) to analyze the principal

antecedents affecting the adoption of open innovation across Indian manufacturing enterprises. Open innovation is influenced not just by internal capabilities but also by external environmental factors, strategic intent, and organizational readiness (Haylemariam et al., 2024b). Therefore, the framework combines both internal and external factors to give a full picture of the things that might help or hinder the adoption of OI (Ahmed et al., 2024b). It has been discovered that seven different ideas, which are independent factors, have the potential to predict the adoption of open innovation. Competitive advantage, market uncertainty, organizational preparedness, and proactivity are the factors that are included in this category (Qu & Kim, 2021). It was believed that each of these factors directly influences the use of open innovation (the dependent variable). The following parts will explain the five assumptions in writing and talk about the idea that each link is based on.

## **2.6 Competitive advantage and adoption of open innovation**

Competitive advantage is a key motivator for firms to innovate. Manufacturing firms pursue open innovation to develop unique products, improve operational efficiencies, and capture new markets enhancing their position relative to competitors. In increasingly dynamic industries, firms that adopt OI can more effectively integrate external technologies and ideas, speeding up innovation and reducing costs (Ahmed et al., 2024b). This creates an advantage not easily replicated by rivals. OI allows firms to respond faster to technological changes and customer preferences, thus strengthening their market position. Moreover, open collaboration with research institutions or technology partners allows firms to access cutting-edge knowledge without bearing full R&D costs. One way to stand out and be the cheapest in India's manufacturing sector where costs are crucial and competition is fierce is to use OI (Singh et al., 2019b). Therefore, it is expected that the desire to gain and maintain a competitive edge would play a significant role in firms' decisions to use open innovation strategies.

*H1: Competitive advantage has a significant positive influence on the adoption of open innovation.*

## **2.7 Government support & policy and adoption of open innovation.**

Government support and favorable policy environments play a vital role in promoting innovation, particularly in emerging economies. Policies that provide financial incentives, tax benefits, innovation grants, or support for public-private partnerships can significantly lower the barriers to adopting open innovation. In India, initiatives like 'Make in India', the Production-Linked Incentive (PLI) schemes, and the Atal Innovation Mission aim to stimulate industrial growth and technological advancement (Ayinaddis, 2023b). These policies often encourage collaboration between academia, research institutions, and private enterprises, aligning closely with the principles of OI. Moreover, regulatory clarity, IP protection frameworks, and infrastructure development foster an environment conducive to knowledge sharing and external collaboration. Indian manufacturing firms, especially SMEs, rely heavily on institutional support to experiment with open models of innovation due to resource constraints (Sarpong et al., 2024). Hence, proactive government policies are expected to not only influence firms' innovation orientation but also provide the structural and financial ecosystem necessary for successful open innovation adoption.

*H2: Government support & policy has a significant positive influence on the adoption of open innovation.*

### **2.8 Innovation & flexibility and adoption of open innovation.**

For a company to be successful with open innovation, it must be innovative and able to adapt quickly to new circumstances. Companies that place a high priority on innovation, exploring new ideas, and taking risks are more likely to make use of technology and ideas that originate from outside sources. It is simpler to employ the ideas of other people in the workplace, according to **Liu (2023)**, if you have the ability to adapt your ideas, techniques, and ways of making choices. When working in a field where things are always changing and need to be modified to match the requirements of each individual customer, you need to be creative and adaptable in order to be successful. Businesses that are open to new experiences and that are able to adjust to novel concepts are more inclined to collaborate with other businesses, educational institutions, and even competitors. They are better equipped to respond to opportunities arising from new technologies or market disruptions. In the Indian context, where traditional hierarchical structures dominate many firms, those that demonstrate internal flexibility and openness to change are more likely to break rigid boundaries and pursue OI (**Petruzzelli et al., 2021d**). Thus, a strong orientation toward innovation and organizational flexibility is positively associated with OI adoption.

- *H3: Innovation & flexibility has a significant positive influence on the adoption of open innovation.*

### **2.9 Knowledge absorptive capacity and adoption of open innovation.**

Knowledge absorptive capacity refers to a firm's ability to recognize, assimilate, and apply external knowledge effectively. It is a critical internal capability for successful open innovation. Firms that lack the ability to absorb and integrate external ideas may fail to benefit from OI efforts, regardless of access to external partners. High absorptive capacity allows firms to evaluate the relevance of external innovations, align them with internal goals, and implement them efficiently (**Radjic & Alkaraan, 2022b**). This capacity is often built through prior R&D experience, employee skill development, and learning-oriented cultures. In Indian manufacturing firms, where skill gaps and resource limitations can pose challenges, building absorptive capacity is essential to realize the benefits of OI. Firms with strong absorptive capabilities can bridge the gap between external knowledge sources and internal application, leading to quicker commercialization of innovations (**Szromek & Bugdol, 2024**). Therefore, absorptive capacity is seen not just as a supporting factor but a foundational requirement for effective open innovation adoption.

- *H4: Knowledge absorptive capacity has a significant positive influence on the adoption of open innovation.*

### **2.10 Market uncertainty and adoption of open innovation**

Market uncertainty—characterized by fluctuating customer demands, technological disruptions, and competitive unpredictability—can serve as a catalyst for innovation. Under high uncertainty, firms are compelled to look beyond traditional innovation strategies to remain agile and responsive. Open innovation offers an adaptive mechanism by allowing firms to tap into diverse external knowledge sources, thus expanding their solution space (**Fu et al., 2024**). For Indian manufacturing firms operating in volatile markets, OI can help reduce the risk of innovation failure by distributing the innovation burden across partners. It also allows for faster prototyping, diversified product development, and quicker access to emerging technologies.

Moreover, OI helps firms monitor trends and align offerings with rapidly changing market needs. While uncertainty increases operational risk, it also incentivizes strategic flexibility making firms more likely to collaborate, crowdsource, and co-develop (Ayinaddis, 2023b). Thus, in dynamic and unpredictable markets, firms may adopt open innovation not only as a growth strategy but also as a survival mechanism.

- *H5: Market uncertainty has a significant positive influence on the adoption of open innovation.*

### **2.11 Organizational readiness and adoption of open innovation**

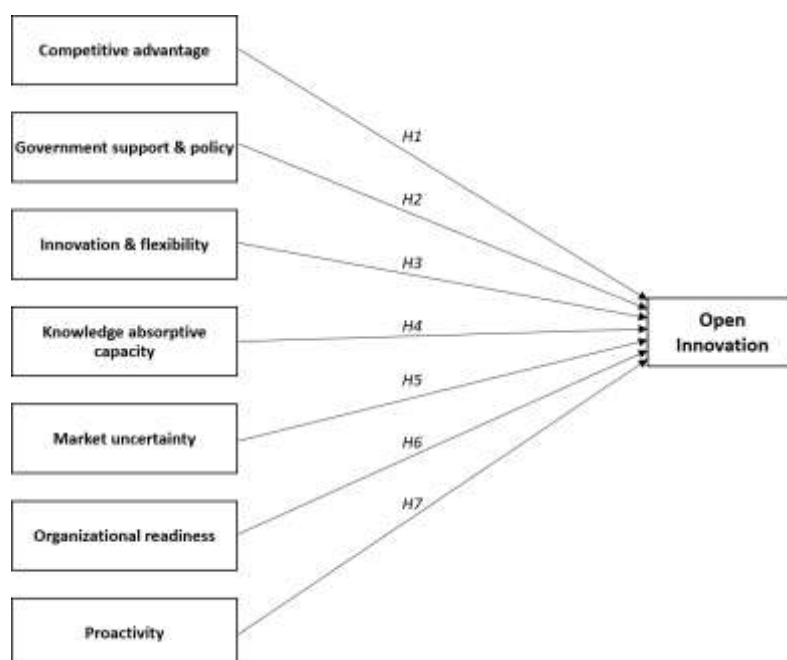
Organizational readiness encompasses the structural, cultural, and technological preparedness of a firm to implement innovation strategies like OI. It includes factors such as leadership support, available infrastructure, digital maturity, cross-functional coordination, and an innovation-oriented workforce (Haylemariam et al., 2024b). Firms that lack readiness may face barriers in managing external partnerships or integrating external ideas. In contrast, ready organizations can rapidly adapt and scale innovation practices. In the Indian manufacturing context, organizational readiness becomes even more critical due to infrastructural diversity, varying levels of digital adoption, and workforce heterogeneity. A firm's ability to adopt OI hinges on having the right internal enablers such as skilled employees, collaborative tools, open communication, and supportive leadership. These elements facilitate effective knowledge exchange and trust with external partners. Organizational readiness thus acts as a mediator that translates strategic intent into actionable innovation practices (Ahmed et al., 2024b). Therefore, firms with high readiness levels are significantly more likely to adopt and benefit from open innovation models.

- *H6: Organizational readiness has a significant positive influence on the adoption of open innovation.*

### **2.12 Proactivity and adoption of open innovation**

Company engages in proactive conduct, it displays that it is prepared to search out fresh opportunities before those prospects become problems or demands. In order to be proactive, organizations must engage in activities such as monitoring developments, searching for trends, embracing new technology at an early stage, and experimenting with new ways to run their operations. During the course of their innovation processes, businesses are encouraged to make use of information and networks from the outside world, which is in line with the principles of open innovation (Marzi et al., 2023). This strategy is in accordance with these principles. Proactive businesses are more likely to collaborate with academic institutions, startups, or other international partners in order to gain access to a wider variety of ideas and resources. This is because proactive businesses are more likely to interact with these types of organizations. Indian manufacturing companies to join early on in collaborative ecosystems, technical developments, and legislative incentives if they take a proactive approach. It increases the robustness of systems to disruptions by making it possible for rapid reactions to be taken. There is a correlation between being proactive and taking risks and fostering an innovative culture, as stated by Szromek and Bugdol (2024). All of these factors are necessary for the successful implementation of organizational innovation implementation. As a consequence of this, firms that are extremely proactive are likely to be more inclined to and capable of efficiently utilizing open innovation strategies.

- **H7:** Proactivity has a significant positive influence on the adoption of open innovation.



### 3. Methodology

#### 3.1 Research objective and design

This study examines the selected antecedents from the perspective of necessary and sufficient conditions to adopt of open innovation by India's manufacturing firms. The study also made efforts to find out the best configurations of the selected antecedents having the maximum impact on the adoption of open innovations by the firms. The study includes five antecedents, identified from the literature review as well as discussion from the industry experts. The antecedents selected for the analysis are **competitive advantage, innovation and flexibility, market uncertainty, organizational readiness and organisational proactivity**. The study examines the selected antecedents wrt their relative importance from the perspective of necessary and sufficient conditions for the adoption of open innovation by the manufacturing firms in India. A conceptual structural model with adoption of open innovation as dependent variable and the selected antecedents as independent variables was proposed and examined using a SEM-PLS, NCA and FsQCA approach. The study adopted *descriptive research design* as research problem, objective, and hypotheses are well defined.

#### 3.2 Data type and sampling design

The primary and cross-sectional responses were collected from 398 senior industry executives with greater than 10 years of experience in manufacturing firms operating in NCR region of India. The respondents were selected on the basis of their exposure and experience about the open innovations adopted by firms in recent years. The interview schedule method was adopted to collect the responses. The responses were recorded by the researcher during the personal discussions with selected industry executives. The discussion started with few criteria questions. The executives who satisfy the criteria were requested to provide their responses to the statements included in the questionnaire. A *judgmental sampling method*, which is a non-

probability method, was adopted to collect the responses. The selection of respondents started with the selection of the industries, the leading firms in the selected industry, followed by the collection of information from firm's websites, and sending requests via email to HR managers for short discussions for research purposes. The few criteria questions were included at the beginning of the discussion to identify whether the respondent were aware of the different open innovations adopted by the firms (yes/no), how they were involved in implementation process for the innovation in the firms, and whether they also aware of the different open innovations adopted by their competitors. The 398 complete responses were collected from respondents over the time period of six months, from Jan 2024 to Aug 2024, which were considered for the final data analysis to fulfil the research objectives. The responses were collected using a 7-point scale ("1 = *strongly disagree*, 2 = *disagree*, 3 = *somewhat disagree*, 4 = *cannot say*, 5 = *somewhat agree*, 6 = *agree*, and 7 = *strongly agree*") used in the questionnaire. The sample size of 398 is assumed as representative as it qualify the criteria of 10 times the number of items/statements included in the structural model (Nunnally, J. C., & Bernstein, I. H., 1994).

### **3.3 Scale development and questionnaire design**

The research instrument adopted in the study was developed in four stages. Stage one started with the identification of the different antecedents (included in the conceptual framework) from the detailed literature review along with the key items and statements measuring them. The draft questionnaire was prepared from the extensive literature review, which is also discussed with industry experts in order to ensure the content validity of the research instrument. In second stage, the draft questionnaire was modified as per the suggestions provided by selected five senior industry executives with more than ten years of industry experience in adopting the open innovations in their firms. The discussion was also made with five academic experts with published research papers on open innovations adopted by the Indian manufacturing firms. The second stage ensures the content validity of the questionnaire as it was properly modified according to the suggestions and reviews provided by the experts. Third stage examine the face validity with a pilot survey conducted with 62 industry executives. The results of the pilot survey were examined wrt the reliability, item duplicity, language consistency and the descriptive analysis of the collected responses etc. The pilot survey helps in further improving the questionnaire by improving the language of the statements, dropping a few statements, etc. Finally, the modified questionnaire was adopted for the final data collection from the respondents.

The questionnaire adapted the items/statements from different research papers. The items measuring *Firms proactivity* were adapted from Feder, 2015; Lumpkin & Dess, 1996; Hansen et al., 2011 and Rauch et al., 2009. The items measuring *Innovation and flexibility* from Cuevas-Vargas et al., 2023; AlMamun et al., 2019; Cuevas-Vargas et al., 2019 and Faul et al., 2009. The items measuring *Competitive advantage* from Dao, 2024; Singh et al., 2019 ; Boso et al., 2012 and Hansen et al., 2011 and the items of *Organizational readiness* were adapted from Qu & Kim, 2024 ; Vega-Jurado et al., 2008 ; Iacovou et al., 1995; Yang et al., 2021, items measuring *Market uncertainty* from Qu & Kim, 2024 ; Chau & Tam, 1997 ; Chatterjee et al., 2021 and Cordeiro et al., 2022. Lastly the items measuring *Open innovation* from Qu & Kim, 2024 ; Davis, 1989 ; and Laursen & Salter, 2005.

### **3.4 Statistical methods**

The different statistical methods were applied in the study on the collected responses to achieve the research objectives. The frequency distribution is used to report the sample demographics.

The internal consistency of the included antecedents and adoption of open innovations in the measurement scale was examined with Cronbach alpha. The construct validity of the questionnaire was examined with ‘*confirmatory factor analysis (CFA)*’ approach, which includes testing of both convergent and discriminant validity of the instrument. The item collinearity was examined for each item in the scale with the help of the ‘*variance inflation factor (VIF)*’. The presence of ‘*common method bias (CMB)*’ in the responses was examined using the ‘*Harman single factor method*’. The structural model was examined using SEM-PLS approach using SmartPLS software. The NCA method was applied to find out the necessary and sufficient condition for the included antecedents in the model. Finally, the FsQCA approach was applied to test the different configurations in explaining the adoption of open innovations by the manufacturing firms in India. The NCA and FsQCA approach was applied due to the reason that the explanation of the included antecedents in defining the adoption of open innovations by the manufacturing firms in India is new contribution to the literature. The next section discusses the results of the statistical analysis applied to the responses.

#### 4. Data analysis and interpretation

This section explains the findings and interpretations of statistical analysis applied to achieve the research objective. The analysis was performed on the primary responses collected from the employees working with different selected manufacturing firms in India and participated in the survey. Section 4.1 represents the demographic details of the employees participated in the survey. Section 4.2 discusses the results of different statistical assumptions examined on the primary responses collected in the survey, which includes testing of the ‘internal consistency reliability’, ‘construct validity’, ‘item multicollinearity’ and ‘common method bias’. Section 4.3 discusses the results of PLS-SEM approach to examine the proposed structural model, followed by NCA method, applied to find out the included antecedents playing the necessary and sufficient roles in adoption of the open innovations in the firms. Sec 4.4 explains the results of FsQCA approach, applied to test the influence of different configurations in adoption of open innovations by the manufacturing firms in India. The research paper finally discusses the identified roles of different selected antecedents in the adoption of open innovation by India's manufacturing firms.

##### 4.1 Sample demographics

The primary responses were collected from the 398 senior industry executives with more than 5 years of experience in manufacturing firms and have knowledge of the extensive innovations adopted by firms in recent years. The sample is assumed as representative of the population, and to arrive at valid conclusions, the responses were collected from industry executives with different demographics. Table 1 demonstrates the frequency distribution of the customers who participated in the survey. The selected demographic variables (*Gender, work experience, age-group, designation and industry*) were included in the sample demographics.

Table 1: Sample demographics

Demographic profile	Sub category	Frequency (%)	
Gender	Male	252	63.3 %
	Female	146	36.7 %
	Less than 10 Years	176	44.2 %

Work Experience	11 to 15 Years	154	38.7 %
	16 to 20 Years	68	17.1 %
Age- Group	Less than 35 Years	126	31.7 %
	36 to 45 Years	153	38.4 %
	46 to 55 Years	83	20.9 %
	Above 55 Years	36	9.0 %
Designation	Junior Manager	104	26.1 %
	Middle Manager	179	45.0 %
	Senior Manager	115	28.9 %
Industry	Automobile	95	23.9 %
	Pharmaceutical	75	18.8 %
	Textile	74	18.6 %
	Electronics	81	20.4 %
	Chemical	73	18.3 %

The results reported in Table 1 represent that out of 398 industry executives working with manufacturing firms in India, participated in the survey, 252 (63.3 %) were males and 146 (36.7%) were females. The results also represent that 176 (44.2%) have work experience less than 10 years, 154 (38.7%) with work experience from 11 to 15 years and 68 executives have experience above 15 years. 126 (31.7 %) of the respondents belong to the age group less than 35 years, 153 (38.4 %) belong to the age group “36 to 45 years” and 83 (20.0%) belong to the age group above 46 to 55 years and remaining 36 above 55 years. Wrt the designation, 104 (26.1%) were junior managers, 179 (45%) gave designation equivalent to middle managers and 115 (28.9%) from senior management of the firms. Finally, the results indicate that the responses were collected from the executives working with manufacturing firms in five industries namely *Automobile (23.9%)*, *pharmaceutical (18.8%)*, *textile (18.6%)*, *electronics (20.4%)* and *chemical (18.3 %)*.

#### 4.2 Reliability and validity analysis

The research paper included the different antecedents in the research instrument (*Competitive advantage*, *Government support & policy*, *Innovation and flexibility*, *Knowledge absorptive capacity*, *Market uncertainty*, *Organizational readiness* and *Proactivity*) as the independent factors influencing the adoption of open innovation by India's manufacturing firms. The instrument quality was examined before testing of the hypothesis and arriving at the conclusions. The Cronbach alpha was applied to examine the internal consistency of the items and reliability of the selected antecedents in the research instruments. The CFA approach is applied to ensure the construct validity of the instrument. Further, item multicollinearity is examined with ‘variance inflation factor’ (VIF) and finally, the ‘common method bias’ in the instrument is tested with the Harman single factor method and marker variable approach.

##### *Reliability analysis*

The reliability of the research instrument was tested with Cronbach's alpha, which is needed to be greater than 0.7 for each construct in the scale. The Cronbach alpha, higher than 0.7, confirms the presence of a significant relationship among the items within a construct. The results of reliability analysis are reported in Table 2. The results indicate that the different constructs included in the research instrument satisfy the requirement of Cronbach alpha higher than 0.7 (*Competitive advantage=0.884*, *innovation and flexibility =0.898*, *market uncertainty=0.912*, *open innovation=0.897*, *organizational readiness =0.867*, *proactivity*

=0.854, *Government support & policy* =0.895 and *knowledge absorptive capacity* = 0.908). Thus, the research instruments used in the research paper confirms the presence of consistency reliability.

### *Construct validity*

The construct validity (convergent and discriminant validity) of the research instruments used in the paper was also examined using the CFA approach. The construct validity of the measurement scale was examined for convergent and discriminant validity, where the convergent validity of the instrument represents high relationship between the constructs and its items, however, the discriminant validity represents that the constructs are different from each other. The convergent validity of the measurement scale consisting of the antecedents of adoption of open innovation was examined with construct loadings of the items included in the study, 'composite reliability' (CR) and 'average variance extracted' (AVE) estimates for each construct in the scale. To confirm the presence of convergent validity of the measurement scale, the required construct loadings of each item is greater than 0.7, and CR and AVE for each construct higher than 0.7 and 0.5 respectively (*Hair et al, 2010*). The discriminant validity of the measurement scale indicating the antecedents influencing adoption of open AI of manufacturing firms, was examined with the HTMT ratio and 'Fornell Larcker criteria'. Both the criteria of HTMT ratio and 'Fornell Larcker criteria' for testing the discriminant validity of the used scale depends upon the cross-loadings between the indicators/items of the different constructs in the measurement scale and are expected to be moderate or low. The HTMT ratio for different pairs of included constructs in the scale is expected to be less than 0.85, whereas, in 'Fornell Larcker criteria', the estimated square root of the AVE of each construct is expected to be higher than its correlation with remaining constructs in the scale (*Fornell, C., & Larcker, D. F., 1981*). Further, the collinearity among the items included in the scale was examined with VIF estimate and is expected to be lower than 3. The results of the CFA used to evaluate the construct validity (convergent and discriminant validity) of the measurement instrument are reported in Tables 3, 4 and 5.

Table 3 indicates that the construct loadings of the items measuring the included constructs in the measurement scale were found to be greater than 0.7, CR and AVE are greater than 0.7 and 0.5 respectively for each construct (*Competitive advantage: CR=0.883, AVE=0.558, innovation and flexibility: CR =0.898, AVE=0.596, market uncertainty: CR=0.911, AVE=0.720, open innovation: CR=0.897, AVE=0.637, organizational readiness: CR =0.867, AVE=0.619, proactivity: CR=0.854, AVE=0.596, Government support & policy: CR =0.895, AVE=0.740, and knowledge absorptive capacity: CR = 0.908, AVE=0.712*). Thus, the results indicate the presence of convergent validity of the measurement scale. For the discriminant validity of the measurement scale, the table 4 reported the results of the HTMT ratio. The result indicates that all the estimated values in the matrix were less than 0.85 supports the presence of discriminant validity. Table 5 reported the results of the 'Fornell Larcker criteria'. The results indicates that the square root of the AVE for each construct in the matrix (first value in each column) was found greater than correlation estimates for each construct in the scale. Thus, the results supported the presence of discriminant validity of the measurement scale. The table 3 also reported the estimated value of VIF for all the items included in the instruments and found less than the required value of 3, ensuring that the scale does not have collinearity issues.

*Statistical fit indices*

The statistical fitness of the measurement model included in the paper is examined with two different statistical fitness indices namely-SRMR and NFI index. The SRMR estimate of the estimated measurement model is 0.038, which is less than the required value of 0.08 and the NFI index is found to be 0.906, higher than the minimum expected value of 0.8. Thus, the statistical fit of the measurement model is found satisfied. The next section discusses the results of hypothesis testing.

**Table 3: Reliability, Convergent validity and item multicollinearity**

	Construct	Construct Loading	Mean (SD)	Cronbach alpha	Composite Reliability	Average Variance	VIF
CA1	Competitive Advantage	0.708	4.96 (1.52)	0.884	0.883	0.558	2.312
CA2		0.856	4.92 (1.52)				1.960
CA3		0.754	4.90 (1.51)				1.917
CA4		0.765	4.86 (1.55)				1.856
CA5		0.725	4.95 (1.53)				2.030
CA6		0.658	4.92 (1.55)				1.952
IF1	Innovation and Flexibility	0.763	4.68 (1.72)	0.898	0.898	0.596	1.958
IF2		0.811	4.75 (1.70)				2.315
IF3		0.800	4.70 (1.78)				2.115
IF4		0.678	4.73 (1.75)				2.048
IF5		0.832	4.69 (1.82)				2.372
IF6		0.737	4.62 (1.77)				2.062
MU	Market Uncertainty	0.838	4.55 (1.55)	0.912	0.911	0.720	3.190
MU		0.883	4.53 (1.52)				2.789
MU		0.871	4.62 (1.43)				2.386
MU		0.799	4.57 (1.58)				3.115
OI1	Open Innovation	0.734	4.82 (1.59)	0.897	0.897	0.637	2.152
OI2		0.786	4.73 (1.52)				2.381
OI3		0.869	4.73 (1.54)				2.561
OI4		0.790	4.77 (1.60)				2.126
OI5		0.805	4.76 (1.59)				2.222
OR1	Organizational Readiness	0.795	4.82 (1.59)	0.867	0.867	0.619	2.100
OR2		0.799	4.91 (1.50)				2.117
OR3		0.795	4.85 (1.56)				1.946
OR4		0.759	4.75 (1.54)				2.172
PRO	Proactivity	0.677	4.98 (1.46)	0.854	0.854	0.596	1.840
PRO		0.805	5.14 (1.34)				1.919
PRO		0.744	4.97 (1.39)				2.043
PRO		0.851	5.13 (1.34)				2.082

Table: HTMT ratio for discriminant validity

	CA	IF	MU	OI	OR	PRO
Competitive Advantage (CA)						

Innovation and Flexibility (IF)	0.647					
Market Uncertainty (MU)	0.726	0.645				
Open Innovation (OI)	0.643	0.580	0.648			
Organizational Readiness (OR)	0.761	0.630	0.805	0.684		
Proactivity (PRO)	0.674	0.592	0.716	0.628	0.820	

Table: Fornell Larcker Criteria for discriminant validity

	CA		MU	OI	OR	PRO
Competitive Advantage (CA)	0.747					
Innovation and Flexibility (IF)	0.647					
Market Uncertainty (MU)	0.726	0.644	0.848			
Open Innovation (OI)	0.647		0.649	0.798		
Organizational Readiness (OR)	0.760		0.805	0.684	0.787	
Proactivity (PRO)	0.672		0.712	0.630	0.816	0.772

Table: Statistical Fitness Index

Fitness Index	Saturated model	Estimated model
SRMR	0.038	0.038
D ULS	0.627	0.627
D G	0.314	0.314
Chi-square	640.788	640.788
NFI	0.918	0.918

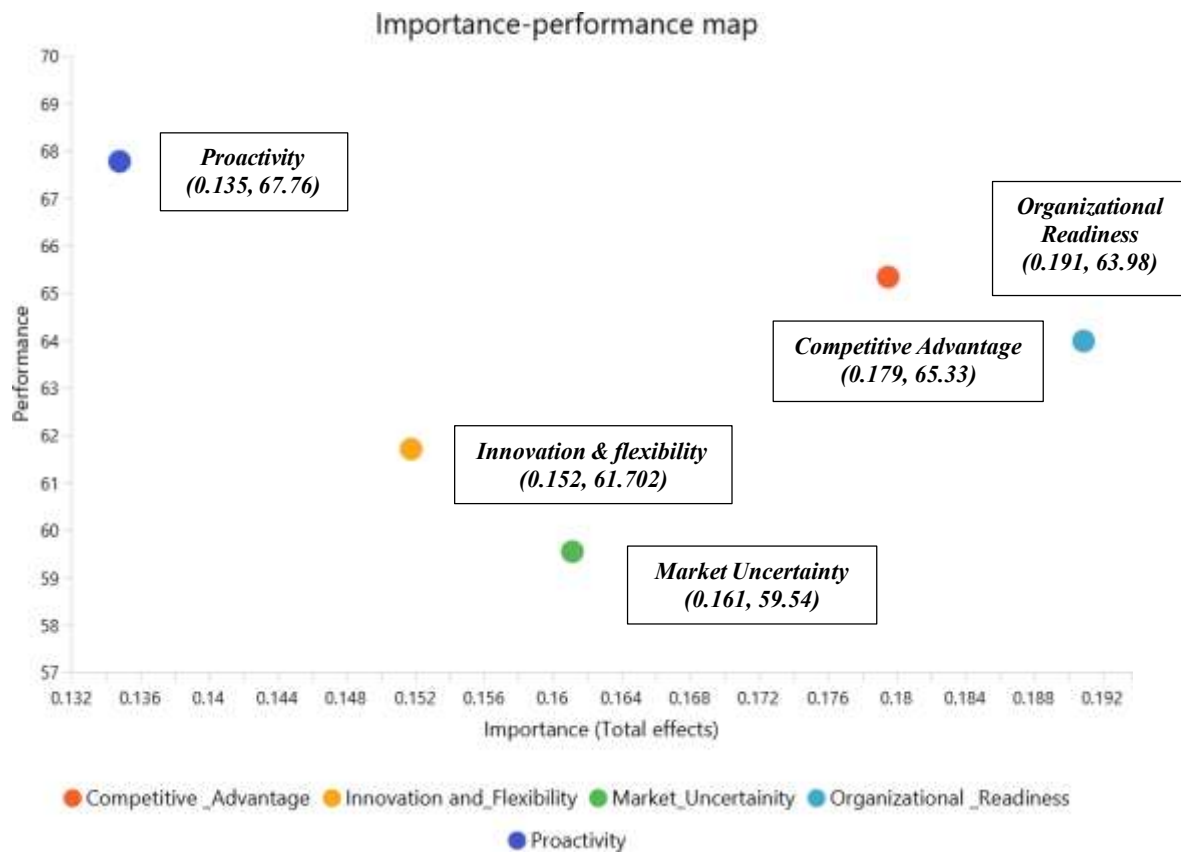
### 4.3 PLS SEM and NCA approach

The paper proposed to examine the structural model, representing the influence of different selected antecedents influencing the adoption of open innovation by India's manufacturing firms. The paper included seven different antecedents in the structural model namely *competitive advantage*, *Government support & policy*, *innovation & flexibility*, *knowledge absorptive capacity*, *market uncertainty*, *organizational readiness* & *proactivity*) as the independent factors influencing the adoption of open innovation by India's manufacturing firms. Here, all are included antecedents are lower order and reflective in nature. Further, adoption of open innovation is an endogenous construct in the structural model and also lower order, reflective construct. Finally, the proposed structural model assumes and examines the influence of the selected antecedents on the adoption of open innovations in Indian manufacturing firms. The seven hypotheses (framed in section 2 of the paper) were examined with the SEM-PLS approach. The results of the hypothesis testing are reported in table 6 and the structural model is shown in figure 2.

Table: Results of the PLS SEM analysis

Exogeneous Construct	Endogenous Construct	Path Coefficient	Standard error	T stats	R Square (Q <sup>2</sup> )	Remark
Competitive advantage	Open Innovation	0.178	0.055	3.255**	47.6 % (.451)	Supported
Innovation and flexibility		0.156	0.057	2.675**		Supported
Market uncertainty		0.158	0.065	2.486**		Supported
Organizational readiness		0.193	0.070	2.739**		Supported
Proactivity		0.133	0.061	2.204**		Supported

The results of the hypothesis testing support the five hypotheses in case of the impact of *competitive advantage, innovation and flexibility, market uncertainty, organizational readiness and proactivity on the adoption of open innovation* in Indian manufacturing firms. The results however failed to support the two-hypothesis indicating the impact of *Government support & policy and Knowledge absorptive capacity* on the adoption of open innovation in Indian manufacturing firms. The path coefficient of all significant antecedents is found to be positive indicating the positive contribution of the selected antecedents on the adoption behaviour of open innovation of the firms. Comparing the path coefficients, the maximum relation contribution is found in case of organisation readiness (path coefficient = 0.209). This is followed by the competitive advantage (path coefficient = 0.184), which also found to have significant positive contribution on the adoption behaviour of open innovation of the firms. The other significant positive impact is found to be in case of market uncertainty ((path coefficient = 0.164), innovation and flexibility (path coefficient = 0.154) and proactivity ((path coefficient = 0.133) on the adoption of open innovation. *Government support & policy and Knowledge absorptive capacity* are not found to have significant influence on the adoption of open innovation in Indian manufacturing firms.



NCA

Percentile	Open Innovation	Competitive Advantage	Innovation and Flexibility	Market Uncertainty	Organizational Readiness	Proactivity
0.000%	1.204	1.976	NN	NN	1.503	NN
10.000%	1.764	1.976	NN	NN	1.503	1.684
20.000%	2.324	1.976	NN	NN	1.503	1.760
30.000%	2.884	1.981	NN	1.727	1.503	2.269
40.000%	3.444	1.981	NN	2.451	1.503	2.269
50.000%	4.005	1.981	NN	2.451	1.503	2.269
60.000%	4.565	1.981	NN	2.451	1.503	2.508
70.000%	5.125	1.981	NN	2.593	1.503	2.508
80.000%	5.685	3.016	NN	2.759	1.503	2.508
90.000%	6.245	4.863	NN	2.759	1.503	4.763
100.000%	6.806 (6.80%)	6.252 (82.66%)	1.510 (0.25%)	6.454 (89.19%)	6.508 (90.95%)	5.416 (54.27%)
Effect size		0.184	0.001	0.210	0.252	0.256
Accuracy		92.965%	99.749%	87.186%	84.422%	94.472%

FsQCA

## 5 Discussion

This study provides insights into the critical factors that influence the adoption of open innovation in manufacturing firms in India. Among the seven antecedents—*competitive advantage, government support and policy, innovation and flexibility, knowledge absorptive capacity, market uncertainty, organizational readiness, and proactivity*—five were found to significantly influence the adoption of open innovation practices. Organizational readiness was the most influential factor (path coefficient = 0.209), indicating that firms with strong internal facilities such as technological infrastructure, leadership support, and an innovation-oriented culture are more likely to adopt open innovation. The resource-based view model emphasizes internal capabilities as key enablers of strategic decisions such as OI adoption in firms. Firms lacking such readiness often face difficulties in managing external collaborations or assimilating external knowledge, reinforcing the literature (Haylemariam et al., 2024b; Vega-Jurado et al., 2008). The second strongest contributor was competitive advantage (path coefficient = 0.184), suggesting that firms seeking to outperform competitors perceive OI as a strategic tool to access external knowledge, accelerate innovation, and deliver differentiated offerings (Singh et al., 2019; Ahmed et al. 2024), as open innovation enhances firms' ability to adapt to market demands and technology disruptions. OI facilitates access to cutting-edge ideas and lowers R&D costs, enabling firms to remain in highly competitive environments. Market uncertainty also showed a significantly positive influence (path coefficient = 0.164), supporting the belief that dynamic and unpredictable environments push firms toward more collaborative and exploratory innovation strategies.

In competitive markets, OI allows firms to share innovation risks, accelerate development cycles, and manage the changes more effectively (Fu et al., 2024; Ayinaddis, 2023) because firms under high uncertain markets often adopt OI as a risk hedging and adaptability mechanism. Innovation and flexibility (path coefficient = 0.154) were also found to positively influence OI adoption, depicting the relevance of a firm's internal culture and adaptability. Firms that value experimentation, flexibility in structure and decision making are better positioned to utilise external knowledge (Liu, 2023; Cuevas-Vargas et al., 2023), suggesting that a culture of flexibility and open-mindedness is necessary for successful external collaboration. Finally, proactivity of the firm (path coefficient = 0.133) found to have a significant impact on adopting open innovation, indicating that the future-orientation and opportunity-seeking firms are more inclined to adopt OI. Proactive firms are more likely to explore external knowledge, innovation and initiate partnerships ahead of competitors (Marzi et al., 2023). The study, however, observed that *government support and policy* did not have a statistically significant impact on OI adoption of the firms (path coefficient = 0.054). This could be due to the perceived gap between policy design and ground implementation in India. Despite programs such as Make in India and PLI, many firms may not feel adequately supported or may lack awareness of or access to these benefits. It also highlights a potential policy-practice disconnect that warrants further investigation. In addition, knowledge absorptive capacity, often seen as a core enabler of OI, was not found to be significant in this context (path coefficient = -0.055). Indian manufacturing firms, particularly SMEs, still struggle with capability development, and may not yet be at a stage where they can effectively utilize external knowledge. Alternatively, absorptive capacity may already be embedded within broader constructs such as organizational readiness.

## 6 Conclusion

This study provides a comprehensive empirical analysis of the key determinants influencing open innovation (OI) adoption among manufacturing firms in India. Grounded in the theoretical frameworks of innovation theory and the resource-based view (RBV), this study examined seven antecedents: competitive advantage, government support and policy, innovation and flexibility, knowledge absorptive capacity, market uncertainty, organizational readiness, and proactivity. This study found that five factors—organizational readiness, competitive advantage, market uncertainty, innovation and flexibility, and proactivity—significantly contribute to the adoption of OI. Among these, organizational readiness emerged as the most influential determinant, underscoring the importance of internal preparedness in terms of leadership support, infrastructure, and collaborative capabilities. Competitive advantage and proactivity further highlight that firms driven by strategic goals and future-oriented innovation behaviors are more inclined to adopt OI practices. The significance of market uncertainty affirms that environmental dynamism encourages firms to seek external collaboration to stay competitive and agile, while innovation and flexibility reflect the cultural adaptability required for open innovation. However, government support, policy, and knowledge absorptive capacity do not significantly affect OI adoption. This indicates potential disconnects between policy implementation and industry perception, and suggests that Indian firms may face internal challenges in leveraging external knowledge despite available government incentives. This study makes two significant contributions to the literature. Theoretically, it validates a context-specific structural model to understand OI adoption in emerging economies, particularly within India's evolving industrial ecosystem. This study provides actionable insights for both managers and policymakers. Firms should focus on enhancing their internal readiness, building flexible innovation cultures, and cultivating proactive strategies. Policymakers, on the other hand, must bridge the gaps in the efficacy of institutional support and strengthen mechanisms to improve absorptive capacity among firms, especially SMEs. The adoption of open innovation in Indian manufacturing is driven more by internal capabilities and strategic intent than by external institutional factors. To realize the full potential of OI, Indian firms must prioritize capacity building and strategic alignment, whereas policymakers must ensure that innovation policies translate effectively into practice.

### *Theoretical and Managerial Implications*

The results indicate the need for firms to invest in building internal enablers, particularly organizational readiness, innovation culture, and strategic proactivity, to fully capitalize on the benefits of open innovation. It also implies that external pressures, such as market volatility, are not necessarily barriers, but can act as catalysts for openness. From a theoretical standpoint, this study advances the open innovation literature in emerging market contexts by confirming the relevance of certain constructs while challenging others. This highlights that traditional enablers such as absorptive capacity may not uniformly apply across contexts and calls for contextualized models that consider institutional maturity and firm-level capability gaps.

## References

- 1 Akjou, A., & Fakhreddine, M. O. I. (2024c). Leaders and Managers Key Characteristics and Open Innovation adoption in SMEs: Systematic review and future directions. *Journal of Innovation Management*, 12(1), 48–76. [https://doi.org/10.24840/2183-0606\\_012.001\\_0003](https://doi.org/10.24840/2183-0606_012.001_0003)

- 2 Abdullah, A. A. H., a, & Almaqtari, F. A., b. (2024). The impact of artificial intelligence and Industry 4.0 on transforming accounting and auditing practices [Journal-article]. *Journal of Open Innovation: Technology, Market, and Complexity*, 10, 100218. <https://fardapaper.ir/mohavaha/uploads/2024/04/Fardapaper-The-impact-of-artificial-intelligence-and-Industry-4.0-on-transforming-accounting-and-auditing-practices.pdf>
- 3 Ahmed, F., Rahman, M. U., Rehman, H. M., Imran, M., Dunay, A., & Hossain, M. B. (2024b). Corporate capital structure effects on corporate performance pursuing a strategy of innovation in manufacturing companies. *Heliyon*, 10(3), e24677. <https://doi.org/10.1016/j.heliyon.2024.e24677>
- 4 Alkaraan, F., Elmarzouky, M., Hussainey, K., Venkatesh, V. G., Shi, Y., & Gulko, N. (2024b). Reinforcing green business strategies with Industry 4.0 and governance towards sustainability: Natural-resource-based view and dynamic capability. *Business Strategy and the Environment*, 33(4), 3588–3606. <https://doi.org/10.1002/bse.3665>
- 5 Appio, F. P., Cacciato, E., Cesaroni, F., Crupi, A., & Marozzo, V. (2024b). Open innovation at the digital frontier: unraveling the paradoxes and roadmaps for SMEs' successful digital transformation. *European Journal of Innovation Management*, 27(9), 223–247. <https://doi.org/10.1108/ejim-04-2023-0343>
- 6 Ayinaddis, S. G. (2023b). The effect of innovation orientation on firm performance: evidence from micro and small manufacturing firms in selected towns of Awi Zone, Ethiopia. *Journal of Innovation and Entrepreneurship*, 12(1). <https://doi.org/10.1186/s13731-023-00290-3>
- 7 Boso, N., Cadogan, J., Story, V. 2012. "Complementary Effect of Entrepreneurial and Market Orientation on Export New Product Success under Differing Levels of Competitive Intensity and Financial Capital," *International Business Review*, 21 (4), p. 667-681.
- 8 Çallı, B. A., Özşahin, M., & Coşkun, E. (2024b). The assessment of organizational innovativeness as a mediator between ICT adoption and firm performance in Turkish SMEs. *SAGE Open*, 14(4). <https://doi.org/10.1177/21582440241297939>
- 9 Camilleri, M. A., Troise, C., Strazzullo, S., & Bresciani, S. (2023b). Creating shared value through open innovation approaches: Opportunities and challenges for corporate sustainability. *Business Strategy and the Environment*, 32(7), 4485–4502. <https://doi.org/10.1002/bse.3377>

- 10 Cepeda-Carrion, I., Ortega-Gutierrez, J., Garrido-Moreno, A., & Cegarra-Navarro, J. (2022b). The mediating role of knowledge creation processes in the relationship between social media and open innovation. *Journal of the Knowledge Economy*, 14(2), 1275–1297. <https://doi.org/10.1007/s13132-022-00949-4>
- 11 Cera, E., & Subashi, R. (2024c). How do commitment-based HRM practices and a developmental culture interact to foster open innovation in SMEs? *Problems and Perspectives in Management*, 22(1), 231–243. [https://doi.org/10.21511/ppm.22\(1\).2024.20](https://doi.org/10.21511/ppm.22(1).2024.20)
- 12 Chatterjee, S.; Rana, N.P.; Khorana, S.; Mikalef, P.; Sharma, A. Assessing Organizational Users’ Intentions and Behavior to AI Integrated CRM Systems: A Meta-UTAUT Approach. *Inf. Syst. Front.* 2023, 25, 1299–1313.
- 13 Chen, A., Li, L., & Shahid, W. (2024b). Digital transformation as the driving force for sustainable business performance: A moderated mediation model of market-driven business model innovation and digital leadership capabilities. *Heliyon*, 10(8), e29509. <https://doi.org/10.1016/j.heliyon.2024.e29509>
- 14 Chien, F., Zhang, Y., & Sadiq, M. (2024c). IMPACT OF OPEN INNOVATION ON GLOBALIZATION: A SURVEY STUDY ON CHINA. *Technological and Economic Development of Economy*, 30(1), 196–217. <https://doi.org/10.3846/tede.2024.19982>
- 15 Cohen, W.M.; Levinthal, D.A. Absorptive Capacity: A New Perspective on Learning and Innovation. *Adm. Sci. Q.* 1990, 35, 128–152.
- 16 Cohen, W.M.; Levinthal, D.A. Absorptive Capacity: A New Perspective on Learning and Innovation. *Adm. Sci. Q.* 1990, 35, 128–152.
- 17 Cordeiro, M.; Puig, F.; Ruiz-Fernández, L. Realizing Dynamic Capabilities and Organizational Knowledge in Effective Innovations: The Capabilities Typological Map. *J. Knowl. Manag.* 2023, 27, 2581–2603.
- 18 Cuevas-Vargas, H., Parga-Montoya, N., Lozano-García, J. J., & Huerta-Mascotte, E. (2023). Determinants of openness activities in innovation: The mediating effect of absorptive capacity. *Journal of Innovation & Knowledge* <https://doi.org/10.1016/j.jik.2023.100432>

- 19 Dabić, M., Daim, T., Bogers, M. L., & Mention, A. (2023b). The limits of open innovation: Failures, risks, and costs in open innovation practice and theory. *Technovation*, 126, 102786. <https://doi.org/10.1016/j.technovation.2023.102786>
- 20 Dabić, M., Posinković, T. O., Vlačić, B., & Gonçalves, R. (2023b). A configurational approach to new product development performance: The role of open innovation, digital transformation and absorptive capacity. *Technological Forecasting and Social Change*, 194, 122720. <https://doi.org/10.1016/j.techfore.2023.122720>
- 21 Davis, F.D. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Q.* 1989, 13, 319.
- 22 Determinants of openness activities in innovation: The mediating effect of absorptive capacity. (2023). In *Journal of Innovation & Knowledge*. <https://doi.org/10.1016/j.jik.2023.100432>
- 23 Determinants of openness activities in innovation: The mediating effect of absorptive capacity. (2023). In *Journal of Innovation & Knowledge*. <https://doi.org/10.1016/j.jik.2023.100432>
- 24 Edquist, C.; Hommen, L. Public Technology Procurement and Innovation Theory. In *Public Technology Procurement and Innovation*; Edquist, C., Hommen, L., Tsipouri, L., Eds.; Economics of Science, Technology and Innovation; Springer: Boston, MA, USA, 2000; Volume 16, pp. 5–70, ISBN 978-1-4613-7084-0.
- 25 Feder, E. (2015). International Entrepreneurial Orientation and Performance of Romanian Small and Medium-sized firms: Empirical Assessment of Direct and Environment Moderated Relations. *Procedia. Economics and Finance*, 32, 186–193. [https://doi.org/10.1016/S2212-5671\(15\)01381-7](https://doi.org/10.1016/S2212-5671(15)01381-7)
- 26 Fu, X., Zanello, G., Contreras, C., & Ding, X. (2024b). Innovation under constraints: the role of open innovation in Ghana. *Industry and Innovation*, 444–474. <https://doi.org/10.1080/13662716.2024.2319798>
- 27 Grant, R.M. Toward a Knowledge-based Theory of the Firm. *Strateg. Manag. J.* 1996, 17, 109–122.

- 28 Hansen, J., Deitz, G., Tokman, M., Marino, L., Weaver, M. 2011. “Cross national invariance of the entrepreneurial orientation scale”, *Journal of Business Venturing*, 26, p. 61-78.
- 29 Hansen, J., Deitz, G., Tokman, M., Marino, L., Weaver, M. 2011. “Cross national invariance of the entrepreneurial orientation scale”, *Journal of Business Venturing*, 26, p. 61-78.
- 30 Haylemariam, L. G., Oduro, S., & Tegegne, Z. L. (2024b). Entrepreneurial agility and organizational performance of IT firms: A mediated moderation model. *Journal of Entrepreneurship Management and Innovation*, 20(2), 75–92. <https://doi.org/10.7341/20242024>
- 31 Iacovou, C.L.; Benbasat, I.; Dexter, A.S. Electronic Data Interchange and Small Organizations: Adoption and Impact of Technology. *MIS Q.* 1995, 19, 465.
- 32 Laursen, K.; Salter, A. Open for Innovation: The Role of Openness in Explaining Innovation Performance among U.K. Manufacturing Firms. *Strateg. Manag. J.* 2006, 27, 131–150.
- 33 Lepore, D., Vecciolini, C., Micozzi, A., & Spigarelli, F. (2023b). Developing technological capabilities for Industry 4.0 adoption: An analysis of the role of inbound open innovation in small and medium-sized enterprises. *Creativity and Innovation Management*, 32(2), 249–265. <https://doi.org/10.1111/caim.12551>
- 34 Liu, L. (2023). Green innovation, firm performance, and risk mitigation: evidence from the USA. *Environment Development and Sustainability*, 26(9), 24009–24030. <https://doi.org/10.1007/s10668-023-03632-z>
- 35 Lumpkin, G., Dess G. 1996. “Clarifying the Entrepreneurial Orientation Construct and Linking it to Performance”, *Academy of Management Review*, 21(1), p. 135-172.
- 36 Marzi, G., a, Fakhar Manesh, M., Caputo, A., Pellegrini, M. M., Department of Management, Mathematics and Statistics (DEAMS), University of Trieste, Trieste, Italy, Department of Management, Lincoln International Business School, University of Lincoln, Lincoln, United Kingdom, Department of Economics and Management, University of Trento, Trento, Italy, Department of Management and Law, University of Rome Tor Vergata, Rome, Italy, Research Centre in Management and Economics (CEGE), Universidade Católica Portuguesa, Porto, Portugal, & Católica Porto Business School, Universidade Católica Portuguesa,

- Rua de Diogo Botelho, Porto, Portugal. (2023). Do or do not. Cognitive configurations affecting open innovation adoption in SMEs [Journal-article]. *Technovation*, 119, 102585. <https://doi.org/10.1016/j.technovation.2022.102585>
- 37 McPhillips, M., Tegtmeier, S., & Nikitina, T. (2024). Going all in or spreading your bet: a configurational perspective on open innovation interaction channels in production sectors. *Production Engineering Archives*, 30(2), 191–203. <https://doi.org/10.30657/pea.2024.30.18>
- 38 Mishra, A. (2024). Empowering AI-Powered Product Companies: Enhancing Design with Knowledge Management, Open Innovation, and Foresight. In OCAD University, *OCAD University*.
- 39 Mubarak, M. F., Tiwari, S., Petraite, M., Mubarik, M., & Rasi, R. Z. R. M. (2021b). How Industry 4.0 technologies and open innovation can improve green innovation performance? *Management of Environmental Quality an International Journal*, 32(5), 1007–1022. <https://doi.org/10.1108/meq-11-2020-0266>
- 40 Najib, M., Ermawati, W. J., Fahma, F., Endri, E., & Suhartanto, D. (2021a). FinTech in the Small Food Business and Its Relation with Open Innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, 88. <https://doi.org/10.3390/joitmc7010088>
- 41 Naseer, S., Khawaja, K. F., Qazi, S., Syed, F., & Shamim, F. (2020c). How and when information proactiveness leads to operational firm performance in the banking sector of Pakistan? The roles of open innovation, creative cognitive style, and climate for innovation. *International Journal of Information Management*, 56, 102260. <https://doi.org/10.1016/j.ijinfomgt.2020.102260>
- 42 Ogiemwonyi, O., a, Alam, M. N., b, Hago, I. E., c, Azizan, N. A., d, Hashim, F., e, & Hossain, M. S., f. (2023a). Green innovation behaviour: Impact of industry 4.0 and open innovation. In *Heliyon* (Vol. 9, p. e16524) [Review article]. <https://doi.org/10.1016/j.heliyon.2023.e16524>
- 43 Oliveira, T.; Martins, M.F. Literature Review of Information Technology Adoption Models at Firm Level. *Electron. J. Inf. Syst. Eval.* 2011, 14, 110–121.
- 44 Patrick Y. K. Chau, & Tam, K. Y. (1997). Factors Affecting the Adoption of Open Systems: An Exploratory Study. *MIS Quarterly*, 21(1), 1–24. <https://doi.org/10.2307/249740>

- 45 Petruzzelli, A. M., Murgia, G., & Parmentola, A. (2021d). How can open innovation support SMEs in the adoption of I4.0 technologies? An empirical analysis. *R and D Management*, 52(4), 615–632. <https://doi.org/10.1111/radm.12507>
- 46 Priyadarshini, A., Gao, Y., & O’Gorman, C. (2024). Firm specific determinants of open innovation in European SMEs. In *Journal of Small Business & Entrepreneurship* (pp. 130–157). <https://doi.org/10.1080/08276331.2021.1907698>
- 47 Pundziene, A., Nikou, S., & Bouwman, H. (2021b). The nexus between dynamic capabilities and competitive firm performance: the mediating role of open innovation. *European Journal of Innovation Management*, 25(6), 152–177. <https://doi.org/10.1108/ejim-09-2020-0356>
- 48 Qu, C.; Kim, E. Investigating AI Adoption, Knowledge Absorptive Capacity, and Open Innovation in Chinese Apparel MSMEs: An Extended TAM-TOE Model with PLS-SEM Analysis. *Sustainability* 2024, 17, 1873. <https://doi.org/10.3390/su17051873>
- 49 Quesado, P., & Silva, R. (2021a). Activity-Based Costing (ABC) and its implication for open innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, 41. <https://doi.org/10.3390/joitmc7010041>
- 50 Rabie, N., Moustafa, A., Al Ghaithi, F., & MDPI. (2024). Organizational practices’ role in managing open innovation and business performance. *Administrative Sciences*, 14, 87. <https://doi.org/10.3390/admsci14050087>
- 51 Radicic, D., & Alkaraan, F. (2022b). Relative effectiveness of open innovation strategies in single and complex SME innovators. *Technology Analysis and Strategic Management*, 36(9), 2113–2126. <https://doi.org/10.1080/09537325.2022.2130042>
- 52 Rauch, A., Wiklund, J., Lumpkin, G., Frese, M. 2009. “Entrepreneurial Orientation and Business Performance: an Assessment of Past Research and Sugestions for the Future”, *Entrepreneurship Theory and Practice*, 33(3), p. 761-787.
- 53 Robertsons, G., Lapins, E., & Heilala, J. (2024b). Exploring relations between methods of assuring quality, certified management systems, adoption of technologies and company performance. *Economics and Culture*, 21(2), 77–90. <https://doi.org/10.2478/jec-2024-0020>

- 54 Sarpong, E. O., Yunfei, S., Coffie, C. P. K., & Akrong, G. B. (2024). Empirical evidence of inbound open innovation practice by Ghanaian SMEs. *SAGE Open*, 1–16. <https://doi.org/10.1177/215824402311964>
- 55 Singh, S. K., Chen, J., Del Giudice, M., & El-Kassar, A.-N. (2019). Environmental ethics, environmental performance, and competitive advantage: Role of environmental training. *Technological forecasting and social change*, 146, 203–211. <https://doi.org/10.1016/j.techfore.2019.05.032>
- 56 Singh, S. K., Gupta, S., Busso, D., & Kamboj, S. (2019b). Top management knowledge value, knowledge sharing practices, open innovation and organizational performance. *Journal of Business Research*, 128, 788–798. <https://doi.org/10.1016/j.jbusres.2019.04.040>
- 57 Szromek, A. R., & Bugdol, M. (2024). Sharing Heritage through Open Innovation—An Attempt to Apply the Concept of Open Innovation in Heritage Education and the Reconstruction of Cultural Identity. *Heritage*, 7(1), 193–205. <https://doi.org/10.3390/heritage7010010>
- 58 Tra, D. T., Man, D. T., Phuong, N. T. M., Tien, D. V., Ha, T. V., Huong, N. T. X., Dung, L. T. P. (2024). The Effect of Operation Management and Open Innovation on Women-Owned Small and Medium Enterprises Performance in Vietnam. *International Journal of eBusiness and eGovernment Studies*, 16(2), 384–401. [doi:10.34109/ijebeg.2024160219](https://doi.org/10.34109/ijebeg.2024160219)
- 59 Tsai, F., Cabrilo, S., Chou, H., Hu, F., & Tang, A. D. (2022b). Open innovation and SME performance: The roles of reverse knowledge sharing and stakeholder relationships. *Journal of Business Research*, 148, 433–443. <https://doi.org/10.1016/j.jbusres.2022.03.051>
- 60 Vega-Jurado, J.; Gutiérrez-Gracia, A.; Fernández-de-Lucio, I. Analyzing the Determinants of Firm's Absorptive Capacity: Beyond R&D. *R D Manag.* 2008, 38, 392–405
- 61 Verona, G.; Ravasi, D. Unbundling Dynamic Capabilities: An Exploratory Study of Continuous Product Innovation. *Ind. Corp. Change* 2003, 12, 577–606.
- 62 Wang, C., Lin, Z., Kumar, N., Zhejiang Normal University, & Zhejiang Normal University. (2022). A Meta-Analysis of the nexus between open innovation and

Innovation Performance: A Moderated mediation Integrated analysis. In Preprint [Journal-article]. <https://ssrn.com/abstract=4776390>

- 63 Yang, M.; Fu, M.; Zhang, Z. The Adoption of Digital Technologies in Supply Chains: Drivers, Process and Impact. *Technol. Forecast. Soc. Change* 2021, 169, 120795.
- 64 Zhang, X., Chu, Z., Ren, L., & Xing, J. (2022b). Open innovation and sustainable competitive advantage: The role of organizational learning. *Technological Forecasting and Social Change*, 186, 122114. <https://doi.org/10.1016/j.techfore.2022.122114>