Small Bus Econ
https://doi.org/10.1007/s11187-025-01156-6

RESEARCH ARTICLE

Unlocking SME innovation success through sequenced collaboration

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Received: 1 February 2024 / Accepted: 9 December 2025

Abstract This study examines how small and medium-sized enterprises (SMEs) sequence their open innovation (OI) activities over the course of individual innovation projects. Moving beyond static firm-level analyses, we explore the dynamics of partner engagement and value capture in 106 European SMEs. Using a dataset of 500 OI activities—termed "OI moves"—we identify patterns that combine partner type and exploitation mode. By comparing more and less successful SMEs, we reveal that sequencing plays a critical role in innovation outcomes. Successful SMEs tend to engage R&D service providers early, prioritize internal exploitation initially, and later transition to co- and external exploitation. In contrast, less successful SMEs rely prematurely on external exploitation and fail to retain value from their innovation efforts. Our dynamic, journey-based approach advances the predominantly static treatment of OI in prior research by operationalizing OI as sequences of linked activities rather than isolated collaboration choices. This enables us to identify a limited set of recurrent pathways associated with successful outcomes, as well as distinct pathways that consistently lead to unsuccessful outcomes. We also highlight the underexplored role of exploitation modes in OI: not just *which* partners SMEs engage, but *when* and under *which value-capture logic*. The sequencing of internal, joint, and external exploitation emerges as a key differentiator between successful and less successful SME innovation strategies. For theory, the study contributes a dynamic process perspective to OI research, demonstrating that value capture is path-dependent and shaped by the temporal ordering of OI moves. For practice, the findings provide actionable guidance of steps for SMEs to follow in order to be successful with OI.

Plain English Summary A machine-learning analysis of 106 SMEs engaging with Open Innovation across Europe shows that the timing of partners engagement and the timing of value capture models are equally important with the selection of partners

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Published online: 10 January 2026

and business models. This study shows how small and medium-sized enterprises (SMEs) can improve innovation outcomes by carefully sequencing their collaboration with external partners and managing how they capture value from those relationships. Analyzing 106 SMEs across Europe, we found that the most successful ones start by exploiting innovations internally before gradually involving partners in joint or external exploitation. They also engage research partners earlier in the process, while less successful SMEs tend to rely too quickly on external partners and lose value as a result. These insights help SME managers make more strategic decisions about when and how to work with external partners during innovation projects. For researchers, the study encourages a shift toward dynamic, project-level analysis of open innovation, focusing not just on partner choice but on the unfolding sequence of collaboration and value capture.

Keywords Open Innovation · SMEs · Machine Learning · OI moves · Innovation pathways · Innovation journeys · Innovation sequencing · Innovation strategy

JEL Classification O36

1 Introduction

Innovation poses significant challenges for small and medium-sized enterprises (SMEs) that account for approximately 99% of all firms and contribute 50–60% of total value added across OECD countries (OECD, 2023). Studies have identified several key obstacles faced by SMEs in implementing innovation, including limited financial resources, a shortage of skilled human capital, and challenging market conditions (Costa et al., 2023; Vanhaverbeke, 2017). To address these challenges, SMEs have increasingly adopted Open Innovation (OI) practices (Radziwon & Bogers, 2019; Usman et al., 2018). This shift has drawn attention from management scholars seeking to develop mechanisms tailored to SMEs' unique organizational characteristics (Usman et al., 2018; Hossain, 2015). Although adopting OI can enhance innovation performance, many SMEs still struggle with effective implementation (Albats et al., 2023).

Existing literature highlights the potential of OI to help SMEs overcome resource constraints and the liability of smallness (Bigliardi & Galati, 2016; Torres de Oliveira et al., 2022). By collaborating with external partners, SMEs can streamline operations, reduce time-to-market, and expand market reach (Dahlander & Gann, 2010; Kapetaniou & Lee, 2019; Wynarczyk et al., 2013). However, much of the research has focused on firm-level analyses, overlooking the finer details of how SMEs manage OI, falling short of addressing the complexity of OI in an SME as a dynamic variant process (Albats et al., 2023; Audretsch & Belitski, 2022) with several forms of knowledge exchanges and potentially several forms of value capturing (Audretsch et al., 2024a; Tsai et al., 2022). In practice, SME manage OI through innovation projects with a starting point and, more significantly, a clear outcome such as a product, a process or a business model innovation (Markovic et al., 2020; Brunswicker et al., 2018). To complete these projects, SMEs often engage in multiple partnerships (Albats et al., 2023), each one associated with a specific type of partner and a particular form of value capturing. The complexity of these arrangements draws attention to the careful sequencing of these steps and in particular the sequencing leading to successful outcomes (Barrett & Tsekouras, 2022; Brunswicker & Vanhaverbeke, 2015), a theme under researched in our ongoing theoretical debate. Given that SMEs can only handle a limited number of OI projects simultaneously, understanding how they manage individual innovation projects is crucial since the degree of success of a project can have major implications for the competitiveness of the relevant SME (Tranekjer & Søndergaard, 2013; Vanhaverbeke, 2017).

To advance our understanding of how SMEs manage OI at the level of individual innovation projects, this paper examines how they engage different types of partners and capture value over time. While existing research has focused largely on firm-level adoption of OI, we take a project-level perspective and investigate how the timing, combination, and progression of OI activities influence innovation outcomes. Specifically, we address three interrelated research questions. First, what are the typical combinations of innovation partners and value capture modes used by SMEs in their OI activities, and how do these combinations differ between more and less successful firms? Second, how do successful and less successful

SMEs differ in the sequencing of partner engagement throughout their OI journeys? Third, how do successful and less successful SMEs differ in the sequencing of value capture modes (i.e., internal, external, and co-exploitation) during their OI journeys? By answering these questions, we aim to move beyond static descriptions of OI practices and uncover dynamic configurations that contribute to the success—or failure—of SME innovation initiatives.

To address these questions, we use a novel mix of methods combining: (a) Multi-case study following the theoretical sampling approach with a purposeful selection of cases to develop insights and identify trends in a variety of SMEs (e.g. high-tech and low-and-medium tech, early stage and established SMEs and SMEs from different economic contexts within Europe) (Zhou et al., 2023). (b) Qualitative coding of written-up case studies to identify the range of OI activities involved in an innovation project as well as the way the capture value from these activities, differentiating between various levels of success (Albats et al., 2023). (c) These data were used as a seed for Machine Learning providing large-scale analysis to identify partnership-value creation configurations and distinguishing between paths of activities in more successful and less successful innovation strategies (Tidhar & Eisenhardt, 2020).

A key construct to enable his analysis was the adoption of the concept of OI moves (Livieratos et al., 2022) which captures both the type of partner involved and the way SMEs capture value through specific modes of exploitation in their OI activities — we call them 'exploitation modes'. We distinguish three key exploitation modes through which SMEs capture value from OI activities: (i) internal exploitation, where an SME is commercially exploiting the innovation outcome internally; (ii) co-exploitation, where the outcome is jointly exploited with a partner (e.g., through joint ventures or revenue-sharing agreements); and (iii) external exploitation, where a third party exploits the outcome while an SME gains value indirectly, such as via licensing or royalties. Building on this framework, we employed a mixed-methods approach that integrates qualitative case-based data collection through semi-structured interviews with machine learning techniques. Specifically, we analyzed 500 OI moves from 106 European SMEs involved in OI projects. In turn, we employed Association Rule Mining, a machine-learning technique, to detect patterns and relationships within the sequences of OI moves. This method identifies frequent "if–then" relationships, revealing how specific combinations of OI moves influence outcomes.

Our findings reveal significant differences in how successful and less successful SMEs approach their OI journeys. Successful SMEs exhibit a pronounced tendency toward internal exploitation early in the process, leveraging initial gains before transitioning to co-exploitation and external exploitation. In contrast, less successful SMEs often rely on external exploitation prematurely, limiting their ability to capture value. Successful SMEs also strategically engage with R&D service providers early, while less successful SMEs tend to involve them later in the process. Additionally, successful SMEs demonstrate flexibility by collaborating with diverse partners, such as communities and crowds, to enrich their innovation outcomes.

By uncovering these patterns, our research provides actionable insights for SMEs looking to optimize their innovation strategies. Effective sequencing of OI moves—particularly the timing of partner engagement and the mode of exploitation—can enhance innovation success, helping SMEs navigate the complexities of OI and achieve sustainable growth.

2 Background of the research

2.1 Partner diversity, value capture, and the dynamics of open innovation activities in SMEs

OI has become an increasingly important strategy for SMEs, offering them a means to overcome internal resource constraints by leveraging external knowledge and collaborations (Audretsch & Belitski, 2020; Chesbrough & Bogers, 2014). In the context of SMEs, this external engagement is not merely a one-off interaction but often unfolds as a *journey*—a dynamic sequence of decisions about which partners to involve and how to capture value from the resulting innovation outcomes. This paper builds on the growing body of research emphasizing that understanding these dynamic sequences—what we refer to as OI journeys—is critical to explaining how SMEs translate OI efforts into successful outcomes.

Central to this analysis is the *OI move* concept, which dissects OI activity into two key dimensions: the diversity of external partners and the firm's approach to capturing value from the collaboration. These OI moves, taken together, form a temporally ordered innovation journey. Research shows that engaging a diverse set of partners—such as customers, suppliers, universities, competitors, or even the crowd—can offer access to a broad range of knowledge and capabilities that enhance innovation outcomes (Audretsch et al., 2024b; Bogers et al., 2019; Livieratos et al., 2024; Van Beers & Zand, 2014). Yet diversity alone does not determine success. The way SMEs capture value from these collaborations—through internal exploitation, co-exploitation, or external exploitation—is equally critical and still underexplored (Livieratos et al., 2022; Bianchi et al., 2010; Saebi et al., 2015; De Groote, 2023).

Our first research question therefore investigates how SMEs organize their OI projects with regard to both partner diversity and value capture logic. As SMEs typically operate under tight resource constraints (Rahman & Ramos, 2010; Usman et al., 2018), they must be deliberate in partner selection and exploitation strategy. Engaging in collaborative innovation may allow SMEs to access complementary resources and reduce uncertainty (Audretsch et al., 2024a; Tsai et al., 2022), but it also introduces strategic and operational risks. For instance, partners might differ in cognitive or cultural orientations (Du et al., 2014), or tensions may arise around intellectual property and control over innovation outputs (Hewitt-Dundas and Roper, 2009; Alexander and Miller, 2018).

These challenges highlight the need for SMEs to not only select the right partners but also to sequence their OI moves in a way that balances experimentation with commercialization—ultimately shaping the performance of the entire innovation project. This leads to our second research question, which explores how sequences of OI moves unfold over time in successful versus less successful innovation projects. While the literature acknowledges that SMEs engage in multiple OI activities simultaneously (Brunswicker & Vanhaverbeke, 2015; Lee et al., 2010), there has been limited attention to how these activities are sequenced and what patterns emerge in different contexts of success.

Finally, our third research question examines whether value is captured differently in successful OI journeys than in less successful ones. Some SMEs may retain full control over innovation outcomes, while others may engage in joint commercialization or license the results to external actors. This variation in exploitation modes raises important questions about the conditions under which each mode is more effective. We contribute to the literature by showing that capturing value from OI is not just a matter of firm capabilities, but also of timing, partner configuration, and the specific pathways taken through the innovation journey (Albats et al., 2023; Livieratos et al., 2022).

In what follows, we build on these foundations to further develop the OI move concept as the core analytical framework for this study.

2.2 The open innovation move concept

To investigate how SMEs organize and implement OI strategies, this study builds on the concept of the 'OI move'—a unit of analysis that dissects the innovation process into granular strategic actions (Livieratos et al., 2022, 2024). Inspired by the ideas of 'strategic move' (Kim & Mauborgne, 2005) and 'organizational move' (Ocasio, 1997), an OI move integrates two foundational elements: (1) the type of partner the SME engages with ('who the SME innovates with') and (2) the chosen mode of value capture ('who exploits the results'). This concept allows us to track how SMEs combine and sequence these elements across their innovation trajectories—what we call their OI journey.

The OI move concept supports our effort to empirically study three interrelated questions: how SMEs structure their partner engagement and value capture efforts; how different types of partners and exploitation choices are sequenced; and how these configurations differ between more and less successful innovation projects. This framing aligns with Albats et al. (2023), who argue that SMEs use OI not only to fill internal resource gaps but also to advance strategic transformations.

While the role of partners in SME OI strategies has received considerable attention (Huttona et al., 2021; Brunswicker & Vanhaverbeke, 2015; Brunswicker & Brunswicker & de Van Vran, 2014; Lee et al., 2010; Batterink, 2009; van de Vrande et al., 2009; Edwards

et al., 2005), the second building block—how value is captured or exploited—remains comparatively underexplored (De Groote, 2023; Hervas-Oliver et al., 2021; Freel et al., 2016; Saebi et al., 2015; Bianchi et al., 2010). To address this gap, we operationalize a typology of OI moves that captures both partner diversity and exploitation modes, offering a structured lens for analyzing how SMEs navigate their innovation pathways (Table 1).

SMEs can collaborate with eight different types of partners in innovation activities:

- R&D services providers: Organizations such as universities or research institutes that offer specialized knowledge and infrastructure (Radicic et al., 2020; Huggins et al., 2019; Vanhaverbeke, 2017; Rayna & Striukova, 2015; Vanhaverbeke & Chesbrough, 2014; Teirlinck & Spithoven, 2013; Deschamps et al., 2013).
- Complementary partners: Non-R&D entities offering capabilities that enhance the SME's own, distinct from suppliers, customers, or users (Chesbrough, 2006; Livieratos et al., 2022).
- Customers: Buyers whose feedback improves product relevance and usability (Tobiassen & Pettersen, 2018; Santoro, 2018; La Rocca, 2016; von Hippel, 2005; Franke, 2013).
- Suppliers: Key players in delivering components and technical expertise necessary for product development (Tsinopoulos & Mena, 2015; Luzzini et al., 2015; Minguela-Rata et al., 2014; Bocken et al., 2014; Vanhaverbeke & Chesbrough, 2014).
- Non-paying (to the focal firm) users: Distinct from paying customers, these users can provide critical design and usability feedback through informal interactions (Brunswicker & Vanhaverbeke, 2015; Enkel et al., 2005; Gans & Stern, 2002; Livieratos et al., 2022).
- Competitors (co-opetition): Engagements with rivals that blend competition and collaboration, often depending on mutual trust (Bouncken & Kraus, 2013; Carayannis & Alexander, 1999; Fernandes et al., 2019; Gnyawali & Park, 2009; Hameed & Naveed, 2019).
- Communities: Actor groups with shared innovation goals that support ideation, learning, and problem-solving (Brandtzaeg et al., 2010; Shaikh & Levina, 2019; West & Lakhani, 2008).
- The crowd: A diverse, distributed group that contributes unique insights, especially useful in solving complex problems (Garcia & Barcena, 2010; Qin et al., 2016; West & Sims, 2018).

In parallel, we analyse how SMEs capture value from these collaborations via three modes of exploitation (Bianchi et al., 2010; Chesbrough, 2003; Livieratos et al., 2012):

- Internal exploitation: The SME exploits the innovation outcome independently, leveraging in-house assets to support commercialization.
- Co-exploitation: The SME and its partner(s) jointly exploit the innovation result, ranging from coordinated internal use to co-commercialization or joint ventures.
- External exploitation: The SME transfers exploitation rights to a third party but retains a share of the generated value.

Table 1 A typology of OI moves for SMEs

Exploitation mode	Internal Exploitation	Co-Exploitation (with a partner)	External Exploitation (via a partner)
Types of partners			
R&D service providers	1	2	3
Complementary partners	4	5	6
Customers	7	8	9
Suppliers	10	11	12
Users	13	14	15
Competitors	16	17	18
Community	19	20	21
Crowd	22	23	24

Livieratos et al. (2022, 2024)

By combining partner type and exploitation mode, we develop a typology that forms the basis for empirical coding of SME innovation projects. This structured approach enables us to identify, compare, and sequence OI moves, thereby shedding light on the dynamic configurations—OI journeys—that contribute to project success or failure.

3 Methodology

The research was conducted as part of the "INSPIRE SMEs" EU research project, investigating how OI is practiced by European SMEs. The mixed-methods design was chosen to enhance the depth and breadth of analysis. Qualitative interviews led to a nuanced understanding of SME innovation projects resulting in the extraction of 500 OI moves. Next, the use of machine learning allowed for systematic pattern identification across the extracted OI moves. This combination facilitates both explanation and generalization, in line with methodological recommendations for studying complex innovation processes (Creswell & Plano Clark, 2018; Tidhar & Eisenhardt, 2020).

3.1 Data collection

Following a multi-case approach outlined by Albats et al. (2023), this study adopts a purposive sampling strategy (Patton, 2015), guided by predefined inclusion criteria to capture the necessary diversity of OI practices among European SMEs. The aim was to achieve contextual richness by selecting SMEs that varied across geographic regions, firm sizes, and business sectors—thereby employing a maximum variation sampling approach to capture a broad spectrum of OI practices of SMEs in Europe (Short et al., 2002). More specifically, the study focused on innovation projects as the initial level of analysis, exploring the actions, activities, and decisions involved (Du et al., 2014). The OI projects focused on either single innovations or clusters of related innovations.

For the research to have broader generalizability, the selection of SMEs was stratified to include diverse geographical and technology contexts (Silverman, 2011). In terms of geographical stratification, European economies were categorized into six regions based on relatively homogenous characteristics: Eastern European economies, Large economies (France and Germany), Scandinavian economies, Small Developed economies (Austria, Switzerland, Belgium, Netherlands, Luxembourg), Southern European economies (Italy, Spain, Portugal, Greece) and UK & Ireland. The aim was an equal portion of cases from each region. SMEs at various stages of the lifecycle (start-ups, established, mature) and different technology levels (high-tech and low-and-medium technology) were searched in each region to ensure a representation as large as possible. The European standard for the size of SME (European Commission, 2005) was used to define SMEs and a threshold of 7% of R&D expenditure in relation to turnover was used to distinguish high-tech from low-and-medium technology cases (Kirner et al., 2009). All selected SMEs had to fulfil two key inclusion criteria: (1) significant level of OI activities, with evidence of innovation projects at least at the prototype stage within the past five years, and (2) clear evidence of both the innovation process and outcome, involving substantial interactions with at least one external partner.On the contrary, companies merely reselling the SME's product or suppliers producing components based on defined specifications were not considered innovation partners.

A heuristic methodology was developed to identify pertinent cases for the research: a practical, experience-based approach designed was used to guide the selection of relevant cases as formal rules or strict procedures may not be available. This heuristic approach aligns with qualitative methodologies advocated by Patton (2015) and Miles et al. (2014), who suggest practical and systematic processes to select information-rich cases. The research team, composed of 23 researchers, used a flexible, iterative, and judgment-based approach relying on their own prior knowledge and expert input to select cases that would be informative or illustrative for the research objectives. This structured procedure follows the recommended qualitative case selection and identification methods described by Creswell and Poth (2016), ensuring reliability and consistency across the dataset. The researchers' team received training to identify through desktop research OI projects conducted by SMEs that satisfy our set criteria. The researchers, including the authors of this paper, gathered information encompassing various aspects, including business characteristics, OI project details, the impact of OI project, the case value (e.g. what makes the case

interesting, what is the reliability of the information), and accessibility information (e.g. contact details). A peer-pairing method was utilized, wherein each researcher was teamed up with a peer researcher to ensure the reliability and the validity of this part of the research process, specifically to confirm that selected cases met predetermined criteria and that data assessments were conducted accurately; this approach helped mitigate individual bias in the case selection and analysis phases (Creswell & Miller, 2000; Patton, 2015).

Out of 349 OI projects led by SMEs across the six European regions identified by the team, 308 met a minimum feasibility threshold (e.g. OI projects with limited or prohibited access to their data such as projects in defence were left out). Following this, the research team was asked to identify a total of 180 projects, 30 in each of the six European regions. The purpose was to choose the cases that represent successful outliers in the particular economic context in SMEs with an innovation or economic performance unusually high for this country. The underlying logic was these successful outliers represent the best potential for learning how OI can be managed in SMEs and more specifically the sequence of OI activities in SMEs.

The selection of the cases was made using one or more of the following criteria:

- Number of patents registered by themselves and launched a product in the market
- Number of patent applications still pending and launched a product in the market
- Turnover change over the last 3 years or since startup (if more than 3 years)
- (Gross or Net) Profit change over the last 3 years or since startup (if more than 3 years).

A range of desktop sources were searched to collect data on the above criteria. International databases like Amadeus as well as other 'local' databases with financial data for SMEs (e.g. ICAP in Greece) were sourced to identify data. Additionally, the local press and the websites of the firms included in the initial list (of 349 OI projects) were also searched to identify further information or leads to other information.

Typical examples include the following. The SweTree Technologies in Sweden have an IP portfolio of more than 150 patents and patent applications active worldwide while Quilts of Denmark in Denmark has 63 patents registered in their name. TOBEA in Greece have acquired 3 patents and 2 industrial designs (an unusual high patenting activity for the Greek standards). As for the financial performance, Nobacco in Greece was founded in 2013 and by 2017 they were reporting turnover of more than €10 million. Deeper Fishfinder in Lithuania was founded in 2012 and by 2017 they reported a turnover of € 9,328,126 and Profit before tax of € 1,140,646. Finally, Curana in Belgium has 61 patents in total and Gross profit of € 1,022,133 in 2017 compared to € 583,635 in 2012.

The researchers were asked to conduct in-depth research into 20 of the total 30 OI projects identified in each region. If access was secured to more than 20 cases, the selection process had to prioritize the 20 cases with the best (innovation or economic) performance. The research aimed to have semi-structured interviews with one or two managers within the focused SME. An interview guide was developed to support the data collection process. The guide included a questionnaire that was aiming to capture data on four themes:

a) the general SME background;
b) the various stages of the innovation project under discussion;
c) the impact on the business;
d) the lessons learned from the experience of this innovation project.

The notion of an innovation project was used in the wider sense including a number of smaller innovation 'acts'; for instance, the wider innovation project of developing a new product may include exchanges with one or more R&D Service providers, joint work with complementary partners, interactions with a customer etc. The innovation project was defined by its focus on a specific innovation outcome (e.g. a new product or a new process) and it will have to include major exchanges with at least one external innovation partner.

The various stages of the innovation project under discussion included the following activities: (i) Trigger Points, i.e. what triggered the specific innovation action; (ii) Development activities, e.g. how the initial concept was developed, the process and the challenges of the actual development etc. (iii) the Commercialisation & Follow-up activities such as the

scaling-up challenges as well as the marketing and promotion ones and the competition strategy including the business model used to exploit the developed innovation. In this way, the respondents' recollection could be gathered on various stages of the focused innovation project, addressing the changes and the shifts within the innovation process (Bahemia et al., 2018; Bessant & Tidd, 2024). As for the innovation project's outcome, evidence was sought for the link between the OI activities and the (innovation or economic) performance of the firm. This approach ensured comprehensive and comparable results. An expert group of 20 innovation management experts—researchers, practitioners, and business consultants reviewed the guide which was also pilot-tested with nine SMEs across the EU to make necessary adjustments.

The research team carried out semi-structured interviews with interviewees from 106 SMEs. For each SME, one or two interviewees from the leadership team were selected to satisfy the following: (a) possessing a comprehensive understanding of their SME's overall operations and (b) having a direct involvement in the OI project. The interviewees were SME leaders such as CEOs, Managing Directors or key managers (e.g. a manager in charge of the specific innovation project) with the interviews taking place between November 2016 and May 2017 and transcribed verbatim soon after. A panel of two internationally leading academics reviewed a sample of the developed cases (12 cases – 2 cases in each region) to ensure reliability and consistency across the total sample.

A total of 120 SMEs and 162 managers were initially interviewed. Each interview lasted between 1.5–2 h. Following the advice of the senior academics who reviewed the collected evidence 14 cases with limited OI activity or insufficient evidence were excluded leading to a final sample of 106 cases. The sample includes SMEs from all European regions (Annex 1—Table A1) and SMEs in manufacturing and services, of different sizes and different levels of technological intensity (Annex 1—Table A2).

3.2 Data coding

A coding framework was created in the form of a typology to systematically classify and categorize the collected evidence (Table 1) – for a similar logic,

Table 2 Rules of OI journeys applied by more successful SMEs

Rule number	Rules	Lift	Count	Order
1	{22} = > {19}	12.5	2	2
2	{19} = > {22}	12.5	2	2
3	{7,9} = > {8}	12.5	2	3
4	{7,8} = > {9}	12.5	2	3
5	{1,7,9} = > {8}	12.5	2	4
6	{1,7,8} = > {9}	12.5	2	4
7	{1,8} = > {9}	9.4	2	3
8	{1,9} = > {8}	8.3	2	3
9	{9} = > {8}	6.3	2	2
10	{8} = > {9}	6.3	2	2
11	{1,19} = > {10}	5.4	2	3
12	{1,10} = > {19}	3.8	2	3
13	{1,4,7} = > {17}	3.6	2	4
14	{1,4} = > {16}	3.3	2	3
15	{4,7} = > {17}	2.9	3	3
16	{4,7} = > {19}	2.9	2	3
17	{19} = > {10}	2.7	2	2
18	{10} = > {19}	2.7	2	2
19	{8,9} = > {7}	2.3	2	3
20	{19,4} = > {7}	2.3	2	3
21	{1,8,9} = > {7}	2.3	2	4
22	{1,4,7} = > {10}	2.3	3	4
23	{1,4} = > {17}	2.2	4	3
24	{16} = > {4}	2.1	2	2
25	{4} = > {16}	2.1	2	2
26	{1,16} = > {4}	2.1	2	3
27	{19,7} = > {4}	2.1	2	3
28	{17,7} = > {4}	2.1	3	3
29	{1,17} = > {4}	2.1	4	3
30	{13,7} = > {4}	2.1	2	3
31	{1,17,7} = > {4}	2.1	2	4
32	{1,10,7} = > {4}	2.1	3	4
33	{13} = > {4}	1.9	7	2
34	{4} = > {13}	1.9	7	2
35	{17} = > {4}	1.8	5	2
36	{4,5} = > {10}	1.8	2	3
37	{4} = > {17}	1.8	5	2
38	{1,8} = > {7}	1.8	3	3
39	{1,10,4} = > {7}	1.8	3	4
40	{1,13} = > {4}	1.7	4	3
42	{10,7} = > {4}	1.7	4	3
42	{1,7} = > {9}	1.7	2	3
43	{1,7} = > {8}	1.7	3	3
44	{1,5} = > {10}	1.6	4	3
45	{4,7} = > {10}	1.6	4	3

Table 2 (continued)

Rule number	Rules	Lift	Count	Order
46	{1,4} = > {13}	1.6	4	3
47	{22} = > {7}	1.6	2	2
48	{7} = > {22}	1.6	2	2
49	{1,9} = > {7}	1.6	2	3
50	{2} = > {10}	1.5	2	2
51	{10} = > {2}	1.5	2	2
52	{1,10} = > {5}	1.5	4	3

see Souitaris et al. (2012) and Graebner (2009). SMEs' OI activities were coded in relation to the two main building blocks of an 'OI move': type of partner (with whom SMEs partner) and exploitation mode (who is further developing and commercially exploiting outcomes OI activities). Typologies of OI partners have been discussed by Brunswicker and Chesbrough, (2018) and responsibilities to commercialize the outcomes of OI activities by Gassmann and Enkel (2004) and West and Bogers (2017). This coding process adopted a data reduction methodology (Strauss & Corbin, 1998). Qualitative researchers frequently employ such an approach when confronted with extensive data or when dealing with multiple cases (Brown & Eisenhardt, 1997; Maitlis, 2005), as it allows to conduct the transition from numerous descriptive codes to a more condensed set of conceptually abstracted codes. For each OI move, interpretative clusters were formulated (Miles & A. Huberman, 1994). These clusters were established based on whether the OI moves exhibited qualitatively similarities or differences in their character and objectives. In crafting these clusters for each OI move, two key questions were addressed: a) is this code similar to that code? (to establish internally consistent clusters), and b) are these codes different from those codes? (to ensure that the clusters were distinct from each other) (Jarzabkowski, 2008).

To validate the appropriability of the level of analysis and the reliability of the coding framework, two researchers who had participated in the data collection process for ten case studies were engaged as co-analysts. (for a similar approach, see Dutton et al., 2001; Isabella, 1990). More specifically, the co-analysts were trained in the coding framework (Miles & Huberman, 1994) and were tasked with identifying the OI moves from their respective case studies and categorize them according to the established coding framework. Additionally, the co-analysts were encouraged to identify any OI moves that might not align with the coding framework. Nevertheless, none of the co-analysts identified any OI moves that deviated from the framework. A comparison was made between two sets of analyses: the one conducted by the authors and the one by the co-analysts. Dividing the number of coding agreements by the total number of coding agreements and disagreements (Miles & Huberman, 1994) yielded initial reliability ratings as follows: co-analyst 1—identification of OI moves: 93%; positioning of OI moves: 97%—co-analyst 2—identification of OI moves: 96%; positioning of OI moves: 91%. The analysis identified a total of 500 OI moves, out of the 106 cases, which were related to the coding framework.To verify the accuracy of the OI moves, the researcher who had been responsible for developing the specific case study was asked to review and confirm all OI moves. If the researcher raised any objections, an effort was made to obtain further clarification and details for this OI move. Finally, the researchers were requested to assess the success of each OI move from the SME's management point of view on a 9-point Likert scale. To ensure consistency, we first developed a clear protocol for our 9-point success scale, explicitly defining what constitutes a "successful" OI move. We used a Likert-type format with symmetrical gradations around a neutral midpoint—an approach conceptually grounded in established evaluation practices aimed at capturing nuanced perceptions of subjectively rated performance or perceived success/failure (for a similar logic, see Cao et al., 2009). The Likert scale was designed to capture perceived success, allowing raters to position each OI move along a nuanced continuum—from "extremely unsuccessful" (1) to "extremely successful" (9)—based on how well the outcome fulfilled with the SME's own strategic intent and contextual expectations. This structure acknowledges that success is not an objective binary, but a subjective judgment influenced by heterogeneous firm-specific strategic aims from prototype development, business continuity and repositioning to scaling across international markets. This comprehensive approach acknowledges the diverse contexts in which SMEs operate, recognizing that definitions of success vary according to firm size, industry, and maturity. Two researchers then piloted the interview instrument

on five SME cases using this protocol, generating concrete examples that formed the basis of our rater training. During training sessions, we demonstrated how to apply the scale to each example case, ensuring the interviewers interpreted the criteria identically. After training, we formally assessed inter-rater agreement by having the two interviewers independently rate the same cases. We checked for any statistical outliers: only two ratings deviated substantially from the others, and in both cases we identified clear, case-specific reasons for the difference. In sum, these steps – well-defined rating rules, pilot-based training with real examples, and quantitative reliability checks – mirror best-practice approaches (engaging multiple raters in structured training and precisely defined rubric criteria) for achieving high inter-rater consistency.

3.3 Data analysis – machine learning

The collected data on the 500 OI moves (e.g. position in the coding framework, its success rating), and the 106 OI journeys represented as sequences of OI moves (one OI journey in each case study), were analysed using machine learning (a similar approach was used by Tidhar & Eisenhardt, 2020). Association Rule Mining (ARM) was employed to analyse the dataset and uncover patterns of co-occurrence that are indicative of underlying structures within the OI processes of SMEs. ARM was chosen for its capability to identify frequent and meaningful "if–then" relationships, known as association Rules, which provide insights into how specific OI activities undertaken by SMEs are interlinked. (Zijian et al., 2001). Each Rule consists of an antecedent (if) and a consequent (then); in this context, the antecedent represents one or more OI moves initiated by an SME, while the consequent suggests subsequent OI moves that may occur as part of their innovation journey.

The choice of ARM is particularly suitable for this research as it allows for the discovery of non-obvious patterns within large and complex datasets, offering a data-driven perspective that complements traditional qualitative analyses (Agrawal et al., 1993; Han et al., 2011). While traditional qualitative methods such as thematic analysis offer deep interpretive insights into innovation processes, they remain inherently subjective and can be limited in systematically identifying complex patterns across large-scale data (Antons, 2020). In contrast, ARM enables researchers to uncover non-obvious yet impactful sequences of OI activities that might otherwise remain hidden or be overlooked through qualitative coding alone (Rosales-Salas et al., 2020). This method ensures that findings are not solely reliant on subjective interpretations but are supported by empirical evidence derived from formal metrics such as support, confidence, and lift (Tan et al., 2019). Additionally, ARM efficiently processes transactional data at a scale beyond the practical limits of traditional qualitative coding, providing comprehensive insights into complex sequences of innovation moves (Antons, 2020). Furthermore, ARM's ability to handle categorical and transactional data aligns well with the structure of the OI dataset used in this study, where OI moves are recorded as discrete events (Zhang & Zhang, 2002). The methodological choice of using machine learning—particularly ARM—to identify patterns within qualitative innovation data has precedents in recent innovation management research. Studies such as Tidhar and Eisenhardt (2020) and Mariani et al. (2022) demonstrate that employing machine learning techniques provides robust empirical validation for qualitative analyses and offers deeper insights into complex innovation processes. Haefner et al. (2021) similarly highlight the value of AI-based analytical frameworks for mapping innovation activities and uncovering non-obvious relational patterns. Thus, the application of ARM in our study aligns with previous attempts following qualitative and mixed-method research within the innovation management literature.

The process of creating association Rules involves systematically examining the data to uncover frequent "if–then" patterns. In other words, these patterns reveal combinations of antecedents (the "if" conditions) and consequents (the "then" outcomes) that frequently co-occur. To identify the most meaningful relationships, the method relies on key measures: *support*, *confidence*, and *lift*.

Support measures how often a specific sequence of OI moves appears across successful or less successful SME innovation journeys in the dataset. Support simply answers: "Does this pattern occur frequently, or is it just an isolated anecdote?" High support means the pattern appears across many SMEs and is therefore a recurring way of organizing OI rather than an exception. This matters because your analysis aims to reveal typical pathways, not one-off cases. For

example, if a Rule such as "if A then B" is observed in 30% of the records, its support is 0.3..

Confidence tells us how likely the next step in the sequence follows once the first step has already occurred. In your context, it answers a conditional question: “If a firm begins with move A, how often do they proceed to move B? It shows that the pattern is not just frequent, but dependable: once SMEs take the first step, the second step tends to follow. Confidence therefore expresses the strength of the temporal link rather than mere frequency. For example, if every time A is observed, B occurs 70% of the time, the confidence of the Rule "if A then B" is 0.7..

Lift compares the likelihood of a sequence happening to how often it should occur if the steps were unrelated. Even if two moves occur often, they might do so independently. Lift checks whether the steps belong together in a way that is more than by chance. A lift greater than 1 shows that the pattern happens more frequently than random co-occurrence would suggest; it signals a meaningful relationship in how SMEs structure their innovation trajectories. High-lift sequences reveal pathways typical for successful/unsuccessful SMEs which occur far more often in the respective group than random patterns in the data. A lift below 1 suggests the opposite: moves that look linked but actually avoid each other when observed across real journeys (Yin-Fu & Wu, 2011).

In this study, we focused on Rules with lift values greater than 1 because they highlight significant relationships that exceed random association. The larger the lift, the stronger and more meaningful the connection between the antecedent and consequent.

By integrating these measures—support to gauge relevance, confidence to assess reliability, and lift to evaluate the strength of relationships beyond randomness—we ensure that the association Rules derived are not only statistically significant but also practically insightful. This approach provides a robust framework for uncovering patterns in the SME innovation data, aiding in the identification of meaningful sequences of OI moves.

We applied Association Rule Mining (ARM) to identify patterns—referred to as "Rules"—that map the sequences of OI moves undertaken by SMEs. To provide deeper insights into the factors driving success, we conducted the analysis separately for two groups: successful SMEs and less successful SMEs. This separation allowed us to compare the OI pathways that are more likely to result in favourable outcomes with those that are less effective.

The analysis produced a ranked list of association Rules, which can be interpreted as segments of OI journeys. For each journey, we calculated the lift to assess the strength of the relationship between an existing set of OI activities (the antecedent) and the likelihood of a subsequent OI move (the consequent). The lift value effectively quantifies how much more likely it is for a particular OI activity to follow a given sequence than if the activities were unrelated. By focusing on Rules with lift values greater than 1.5, we ensured that the identified pathways represent strong connections between OI moves.

The results revealed a final set of 52 Rules derived for successful SMEs, and 32 Rules for less successful SMEs. This filtering process eliminated weaker associations and retained only those pathways that demonstrate a substantial likelihood of forming part of an impactful OI journey. For the successful SMEs, the Rules highlight sequences of activities that are statistically more likely to contribute to positive outcomes. In contrast, the Rules derived for less successful SMEs provide insights into paths that lead to suboptimal innovation outcomes.

4 Comparing more successful and less successful smes: open innovation journeys

This section presents findings based on the 500 OI moves identified among 106 European SMEs that have participated in OI projects. Our goal is to compare more successful and less successful SMEs and understand how these two sets of firms use different OI journeys when they engage in OI projects.

4.1 Understanding concepts and measures

We identify recurring sequences of OI activities—called “Rules”—that appear across SMEs’ innovation pathways. Tables 2 and 3 summarize the most frequent Rules for more and less successful SMEs, respectively. Each Rule represents a commonly observed pattern in how SMEs sequence different OI moves.:

Each table contains five key pieces of information:

Table 3 Rules of OI journeys applied by less successful SMEs

Rule number	Rules	Lift	Count	Order
1	{1,4,5} = > {9}	7.3	2	4
2	{4,5} = > {9}	5.5	2	3
3	{10} = > {2}	3.7	2	2
4	{2} = > {10}	3.7	2	2
5	{1,5} = > {9}	3.7	2	3
6	{1,4} = > {9}	2.8	2	3
7	{9} = > {5}	2.4	2	2
8	{1,9} = > {5}	2.4	2	3
9	{4,9} = > {5}	2.4	2	3
10	{1,4,9} = > {5}	2.4	2	4
11	{5} = > {9}	2.4	2	2
12	{4,7} = > {10}	2.4	2	3
13	{10,4} = > {7}	2.2	2	3
14	{9} = > {4}	1.8	2	2
15	{4} = > {9}	1.8	2	2
16	{5,9} = > {4}	1.8	2	3
17	{1,9} = > {4}	1.8	2	3
18	{10,7} = > {4}	1.8	2	3
19	{1,5} = > {2}	1.8	2	3
20	{4,7} = > {8}	1.8	2	3
21	{1,8} = > {4}	1.8	2	3
22	{1,7} = > {4}	1.8	3	3
23	{1,5,9} = > {4}	1.8	2	4
24	{1} = > {13}	1.7	2	2
25	{1} = > {9}	1.7	2	2
26	{13} = > {1}	1.7	2	2
27	{9} = > {1}	1.7	2	2
28	{5,9} = > {1}	1.7	2	3
29	{4,9} = > {1}	1.7	2	3
30	{2,5} = > {1}	1.7	2	3
31	{2,4} = > {1}	1.7	2	3
32	{4,5,9} = > {1}	1.7	2	4
33	{8} = > {7}	1.7	3	2
34	{7} = > {8}	1.7	3	2
35	{1,2} = > {5}	1.6	2	3

- Rule number: A number for reference, matching the sequences shown in Table 1.
- Rules: the actual sequence of OI moves—a particular "step" within the overall OI process.
- Lift: A measure of how likely a Rule is to occur compared to random chance. A higher lift suggests that the sequence is more relevant or characteristic for that group.. For (less) successful SMEs, higher lift values suggest Rules that are more strongly associated with (less) successful innovation outcomes. The Rules are ranked in descending order based on their lift values.
- Count: The number of times this Rule was observed in the data.
- Order: The number of steps in the sequence—i.e., how many activities are linked together in the Rule. Higher-order Rules show more complex patterns.

This framework allows us to identify which sequences are most distinctive for successful vs. less successful SMEs.

4.2 Patterns emerging from the open innovation 'rules

The comparison between Table 2 and Table 3 offers a several insights, regarding the smaller OI 'trips' SMEs undertake in the wider OI 'journey'.

4.2.1 Similar complexity, different outcomes

Surprisingly, the complexity of the OI journey—measured by the number of steps in a Rule (last column in both tables)—is very similar between the two groups. Rules with two steps make up 31% of those observed among more successful SMEs and 34% among less successful ones. Rules with three steps account for 54% in both groups, and four-step Rules appear in 15% of successful SMEs versus 11% in the less successful group. In short, success is not simply about engaging in longer or more complex OI sequences (Table 4).

4.2.2 Flexible sequences, similar pairs

In both groups, two-step Rules featuring pairs of OI moves are common. These pairs often appear in different orders, suggesting that the sequence itself – what comes first and what last- is less important than their combination for these pairs.[1]

[1] For example, Rules #1 and #2, and #9 and #10 in Table 2, mirror similar flexibility seen in Rules #3 and #4 or #7 and #11 in Table 3.

Table 4 A comparison of OI exploitation modes between successful and less successful SMEs

	Successful SMEs		Less successful SMEs	
Exploitation mode	Antecedent	Consequence	Antecedent	Consequence
Internal exploitation	79%	69%	55%	54%
Co-exploitation	14%	21%	26%	26%
External exploitation	7%	10%	19%	20%
Total (#/100%)	98	52	62	35

4.3 What sets successful SMEs apart

Third, comparing the top 10 Rules of OI journeys applied by more successful SMEs (Table 2) with the Rules of OI journeys applied by less successful SMEs (Table 3) we can draw interesting insights.

4.3.1 More willingness to work with communities and crowds

One major difference lies in the use of emerging OI partners such as user communities and crowds. More successful SMEs frequently collaborate with these groups—see, for example, Rules #1 and #2 in Table 2—while less successful SMEs almost completely avoid them. These collaborations are usually paired with internal exploitation, allowing SMEs to benefit directly from insights gathered.

Example: Deeper (Lithuania).

Deeper develops smart fishing devices for a traditionally conservative customer base. The founders used crowdfunding, engaged online angling communities, involved influencers, and organized a hackathon ("Maker Fest") to source ideas and feedback. These efforts helped shape the product and encouraged adoption among sceptical users.

4.3.2 More diverse use of customer collaborations

Both SME groups commonly collaborate with customers, but the way they combine customer input with exploitation strategies differs. More successful SMEs tend to use all three exploitation modes—internal, co-exploitation, and external—when working with customers (e.g., Rules #3, #4, #9, and #10 in Table 2). In contrast, less successful SMEs rely heavily on external partners to commercialize their innovations with customers (see Rules #1–10 in Table 3).

This suggests that more successful SMEs possess stronger capabilities in managing OI outcomes and integrating customer feedback into their own business models. They can also switch between different exploitation strategies more flexibly.

Example: Aptual (Finland).

Aptual shifted from digital marketing to creating 'Johku,' a web shop platform. This pivot combined R&D collaboration (with a Belgian partner in an EU project) and customer input gathered through events like Slush. Aptual reused software from past customer projects and engaged in internal, co-, and external commercialization. For example, it licensed the platform to Alma Media (external), shared revenue with cottage-booking platforms (co-exploitation), and continued in-house development (internal).

Fourth, although OI with a customer (OI moves 7, 8 and 9) is a prominent form of OI for both successful and less successful SMEs, they are combined with different modes of exploitation in the two groupings of SMEs. In particular, Rules 3 and 4 in Table 2 suggest that successful SMEs engage with customers using all modes of exploitation (internal, external and co-exploitation) compared to less successful SMEs that concentrate more on engaging with the customer via external exploitation.

4.4 The dynamics of exploitation modes in open innovation

When comparing how successful and less successful SMEs sequence different modes of exploitation within their OI journeys, two important differences emerge.

First, more successful SMEs rely much more on internal exploitation—developing and commercializing outcomes themselves—than on co-exploitation or external exploitation. This implies that they are better positioned to capture the value they create through OI, retaining strategic control and avoiding dependence on external parties. Internal exploitation early in the journey gives these firms more flexibility in later

stages to choose partners and define collaboration terms.

Second, the timing of exploitation modes varies between the two groups. More successful SMEs use internal exploitation primarily at the start of their OI sequences and then transition toward co-exploitation and external exploitation. This suggests a deliberate strategy: they first consolidate innovation outcomes internally and then expand via partnerships to reach broader markets. In contrast, less successful SMEs show no clear shift. Their internal, co-, and external exploitation modes appear randomly throughout the journey, indicating a lack of structured sequencing or limited internal capacity.

Example: Lékué (Spain).

Lékué transformed from a white-label manufacturer into an innovator of silicone kitchenware. It began with internal development—working with Fundació Alicia and designer Luki Huber to create solutions based on real user behavior. Only once the concept was validated and a strong internal base established did Lékué scale internationally, using subsidiaries and partners to co-exploit the innovation abroad.

Counterexample: Company A (Lithuania).

Developed a novel blinds system in collaboration with a university, filed a patent, and relied entirely on a local manufacturer to commercialize. The partner showed initial commitment but failed to mobilize internal support. With no fallback plan or in-house capabilities, the project was abandoned.

More successful SMEs thus treat internal exploitation as a springboard—ensuring that they create something valuable before turning to others for scaling. Less successful SMEs tend to outsource exploitation prematurely, leaving them vulnerable to partner inaction or misalignment.

4.5 The dynamics of open innovation partners

We also examined how different types of OI partners are positioned in the SMEs' sequences—whether they appear early (antecedent) or later (consequence) in the OI journey—and how this timing differs between successful and less successful firms. (Table 5).

4.5.1 R&D service providers

Successful SMEs involve R&D partners at the beginning of the OI journey. This early engagement helps them generate foundational knowledge, technology, or prototypes which can then be developed further in-house or through carefully selected partners. Less successful SMEs, by contrast, involve R&D providers in both early and late phases, often for co-exploitation. This more diffuse involvement suggests that these firms do not use R&D inputs as a strategic

Table 5 A comparison of OI partners between successful and less successful SMEs

	Successful SMEs		Less successful SMEs	
OI moves	Antecedent	Consequence	Antecedent	Consequence
1	24%	0%	21%	20%
2	1%	2%	6%	6%
4	15%	23%	19%	20%
5	2%	2%	16%	14%
7	18%	13%	8%	6%
8	7%	10%	3%	6%
9	7%	10%	19%	20%
10	7%	13%	21%	6%
13	3%	4%	6%	3%
16	3%	4%	0%	0%
17	4%	8%	0%	0%
18	0%	0%	0%	0%
19	5%	8%	0%	0%
22	2%	4%	0%	0%
Total (#/100%)	98	52	62	35

starting point but rather reactively bring them in when facing hurdles.

Example: Lékué (as above) used early-stage R&D collaboration to inform and guide its innovation process internally.

Counterexample: Company B (Czech Republic) licensed a technology from a university but lacked the capabilities to utilize it. The non-exclusive license went unused.

4.5.2 Complementary partners

Both groups collaborate with complementary partners—such as designers, IT integrators, or industrial allies—but again the difference lies in how they exploit the results. More successful SMEs tend to exploit such outcomes internally, integrating the complementary input into their own business models. Less successful SMEs more often share commercialization (co-exploitation), which reduces their ability to shape strategy or revenue capture.

Example: I-perform (Norway) worked with partners in EU and national projects to co-develop its 'Cluster Portfolio' methodology but kept commercialization in-house.

Counterexample: Company C (UK) co-exploited an innovative ingredient with a powerful Belgian distributor, losing influence and flexibility as the partner took the lead.

4.5.3 Customers

Collaboration with customers is common for both groups, but the sequencing again differs. More successful SMEs bring in customers early to shape the innovation and then exploit results themselves or through mixed modes. Less successful SMEs rely heavily on customers in later stages—often for external exploitation—which can shift value capture away from the SME.

Example: Altechna (Lithuania) co-developed a product with a Korean partner, retained the patent, and later licensed it to a Chinese firm—keeping value pathways under its control.

Counterexample: Company A, discussed above, relied entirely on customer-led exploitation, which fell through.

4.5.4 Suppliers

Supplier engagement also differs in timing. Successful SMEs bring in suppliers after key elements of the solution have been developed—often after an initial R&D stage—while less successful SMEs bring them in too early or in roles that limit their own influence.

Example: Jump Research (UK) used a university design module to ideate a new vehicle concept, then brought in a supplier (Rockinvan) for development—preserving ownership over the concept.

Counterexample: Company D (France) partnered early with a large UK manufacturer for co-exploitation. The supplier pursued a competing technology, derailing the project and discouraging further OI efforts.

4.5.5 Teaming up with unconventional partners

Finally, more successful SMEs show greater willingness to engage with less conventional OI partners, such as competitors, communities, or crowds. These partners can offer fresh insights, scale effects, and user engagement—but they require skillful orchestration. Less successful SMEs rarely attempt such collaborations, potentially missing out on valuable opportunities.

Deeper (Lithuania) illustrates this well. It leveraged crowdfunding and community input to develop a disruptive consumer product—something less successful SMEs in our study almost never attempted.

Timing and positioning of partners are as important as the choice of partners themselves. More successful SMEs are more intentional in how they sequence partner involvement, matching them to different stages of value creation and capturing activities.

5 Open innovation pathways of more successful and less successful smes

5.1 Explaining concepts and measures in dynamic directed graphs

New insights were gained by presenting the Rules for both types of SMEs in the form of a dynamic directed graph (Figs. 1 and 2). The graphs show the resulting network bundling all 'Rules' (with & lift value > 1.5)

for successful and less successful SMEs respectively. The graphs include:

a) **OI moves** (also referred to as "positions") are based on the typology framework we introduced in Table 1. Each OI move combines a type of partner with a way of exploiting the outcome. For example, OI move #1 refers to 'collaboration with R&D service providers with internal exploitation of the result'). These OI moves are shown as rectangles in Graphs 2 and 3.
b) **Rules** show how certain OI moves tend to follow one another in a sequence, forming typical OI pathways. In the graphs, each rule is represented as a circle (node). The size of the circle shows how often the rule appears in our dataset—larger circles indicate more frequent patterns. The color of the circle reflects how strongly the rule is associated with successful OI outcomes, measured by "Lift": darker red circles signal rules that occur more often than expected among the SMEs studied.
c) **Edges** (the arrows between the rectangles and the circles) indicate how SMEs transition from one OI move to the next one in an OI journey. They link the moves in our typology (see Table 1) into sequences.

Overall, these graphs allow us to visualize the full network of OI moves and rules. They help us see which OI moves are most central, how they are connected to others, and how they contribute to more or less successful OI strategies.

5.2 Analysing the OI journeys of more successful SMEs

The OI journeys of more successful SMEs reveal several distinct characteristics, as shown in Fig. 1.

5.2.1 A clear structure with strategic starting points

Two OI moves stand out as central: OI move 1, which involves collaboration with R&D service providers combined with internal exploitation of the results; and OI move 7, which refers to collaboration with customers, again with internal exploitation. In the network graph, OI move 1 appears only as a starting point—no other OI move leads into it—indicating that successful SMEs tend to begin their OI activities with R&D partners such as universities or research organizations. Meanwhile, OI move 7 appears both at the start and later in the journey, reflecting that collaboration with customers happens both early and late in the process. In both cases, successful SMEs retain primary control over how the value from these collaborations is used. This reinforces that early experimentation takes place under internal control, before progressively involving customers in later phases.

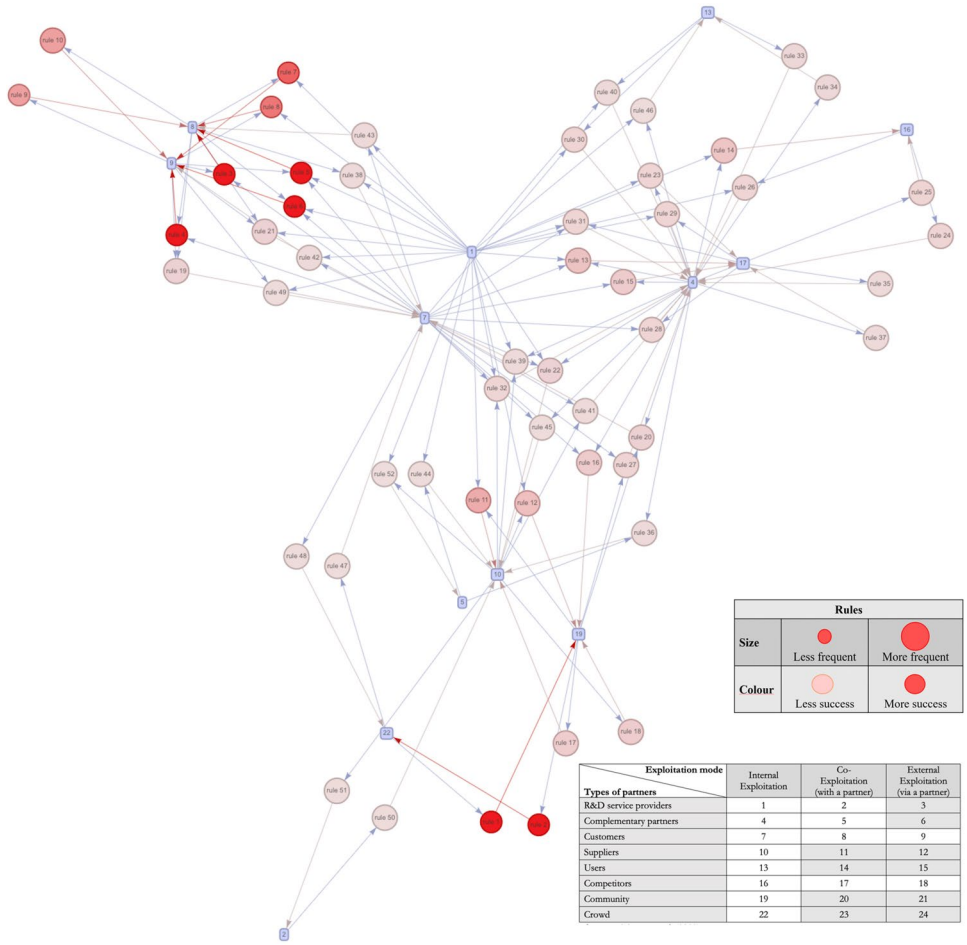
5.2.2 Flexibility in customer exploitation

Another clear pattern is the structure of the "northwest" section of the graph, where we see OI moves 8 and 9. These refer to co-exploitation and external exploitation with customers. Successful SMEs often move from internal exploitation (OI move 7) toward co- or external exploitation (OI moves 8 and 9), but the key takeaway is not the shift itself. Successful SMEs combine all three exploitation modes across their journey, demonstrating adaptability rather than a single preferred mode. This is captured in Rules such as 3, 4, and 19.[2]

5.2.3 From research to markets: an iterative cycle

Successful SMEs also follow a frequent pattern: they start with R&D partnerships and then engage with customers. Often, the journey begins with internal exploitation of R&D outcomes, moves to customer collaboration (co- or external exploitation), and then loops back to internal exploitation again. This reflects an iterative process, not a linear one, in which firms refine and adapt both their technology and value logic. This pattern is seen in multiple rules,[3] showing that SMEs don't treat research and markets as separate stages but as mutually reinforcing phases. This iterative behaviour is confirmed by rules such as {8,9} ⇒ {7} and {1,7,9} ⇒ {8}, which show repeated transitions between these phases.

[2] Rules 3 and 4 show transitions from internal to co-/external exploitation; Rule 19 shows the reverse direction.
[3] Rules 5–8, 21, 28, 42, 43, and 49 illustrate iterative cycles between R&D and customer collaboration.



Types of partners \ Exploitation mode	Internal Exploitation	Co-Exploitation (with a partner)	External Exploitation (via a partner)
R&D service providers	1	2	3
Complementary partners	4	5	6
Customers	7	8	9
Suppliers	10	11	12
Users	13	14	15
Competitors	16	17	18
Community	19	20	21
Crowd	22	23	24

Fig. 1 Pathways typical for OI journeys of more successful SMEs

5.2.4 Integration of broader partner networks

Looking to the right and bottom parts of the network, we see how OI moves 1 and 7 connect with moves like OI move 4 (working with complementary partners), OI move 10 (collaboration with suppliers), and OI move 17 (collaboration with competitors). This part of the network involves more complex partner ecosystems. These SMEs often begin with R&D service providers and customer collaborations and later bring in partners that can support scaling, complementary capabilities, or broader market entry. The rules associated with these pathways[4] emphasize how successful SMEs expand their partnerships gradually while maintaining coherence in their innovation journey. This gradual expansion underscores cumulative, rather than opportunistic, partnering.

5.2.5 Dynamic and flexible partner selection

Lastly, we observe that OI moves 1 and 17 are also connected to OI moves 10 and 19—meaning that collaborations with suppliers and communities are often interrelated. In practice, this suggests that successful SMEs don't stick to one type of partner but dynamically alternate between communities and suppliers, depending on the needs of the project.

[4] Rules 13, 15, 22, 23, 28, 29, 31, 32, 35, 37, 39, 41, and 45 show interactions with complementors and competitors.

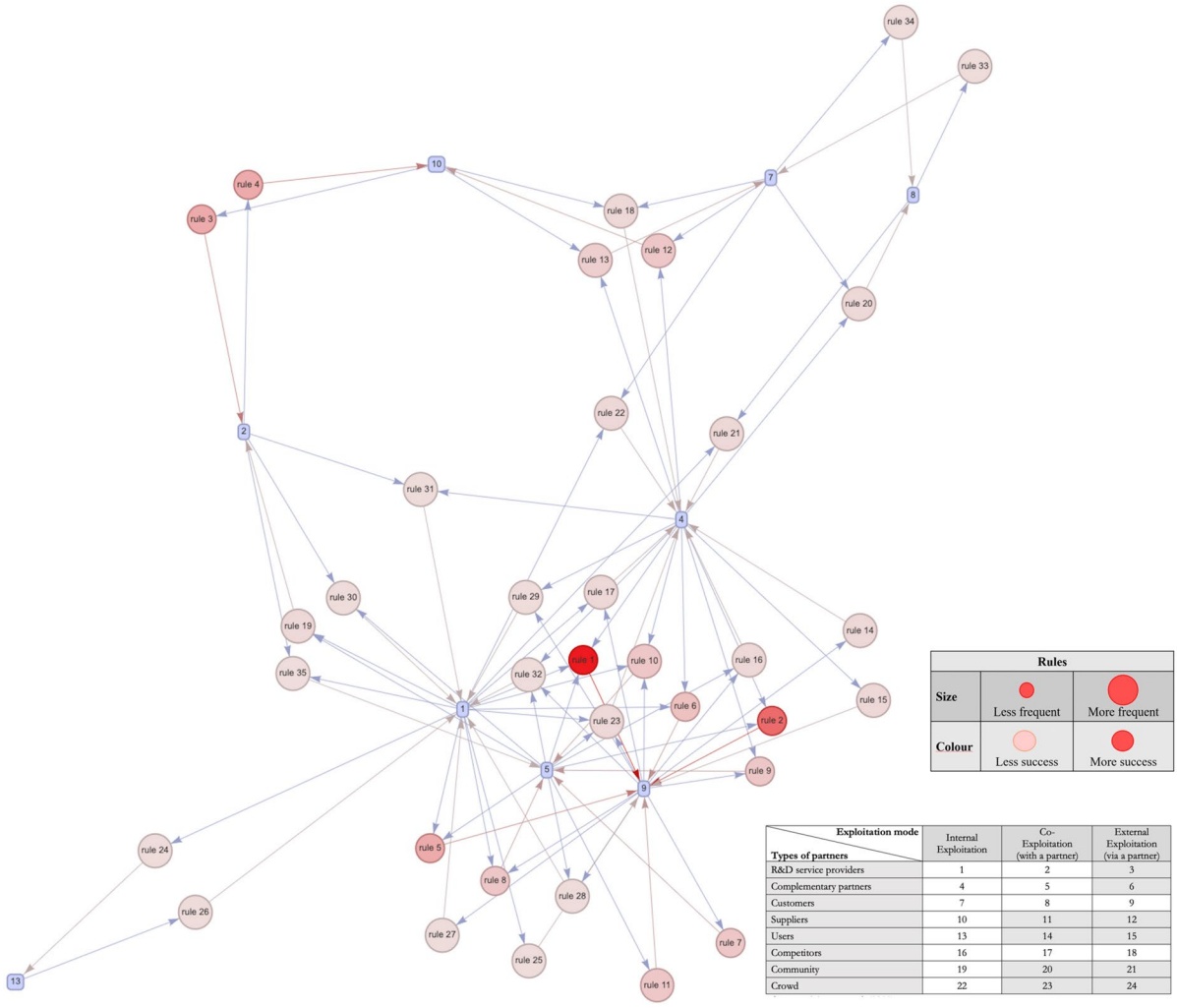


Fig. 2 Pathways typical for OI journeys of less successful

Rules associated with this pattern[5] show how SMEs leverage flexible partner combinations as part of their OI strategies.

5.3 Analysing the OI journeys of less successful SMEs

Figure 2 presents the OI network of the less successful SMEs, and differs in striking ways.

5.3.1 Missed connections between key OI moves

First, there is no visible connection between the initial, internal customer collaboration (OI move 7) and later stages of customer exploitation (OI moves 8 and 9). Instead, OI moves 1 and 9 dominate. This suggests that less successful SMEs often collaborate with customers too late or only in ways where the customer captures most of the value. Internal collaboration with customers (OI move 7), which is key for value capture and product refinement, is missing from the center of their journeys. While OI move 1 is present, it does not anchor the journey but appears mid-sequence, reducing strategic leverage.

[5] Rules 11, 12, 17, and 19 show interchanges between suppliers and communities as downstream or lateral collaborators.

5.3.2 R&D collaborations arrive too late

Second, unlike their more successful counterparts, less successful SMEs do not start their OI journey with R&D partnerships. Instead, they often begin with complementary partners, users, or even customers. Collaborations with R&D service providers happen later, which seems to reduce their effectiveness. This sequence may mean that ideas are not sufficiently matured before being brought to market, or that opportunities for technical differentiation are missed. This timing suggests R&D serves corrective purposes rather than shaping early direction.

5.3.3 Co-exploitation is overused

Third, we observe a central role for OI move 5—co-exploitation with complementary partners. This suggests that these SMEs are often sharing value too early or too generously, particularly with larger or more powerful partners. Table 3 confirms that 19 of the 35 most frequent Rules in this group involve OI moves 9 and 5. Eight of the top ten Rules show customer or partner capture of value.[6] This dominant presence of OI moves 9 and 5 reflects a pattern of early value leakage and weaker bargaining positions.

5.4 Comparing open innovation pathways in more and less successful SMEs

The side-by-side comparison of Figs. 1 and 2 reveals important differences in how more and less successful SMEs structure their OI journeys. These differences go beyond isolated partner choices or singular moves; they concern the sequencing of collaborations, the timing of value capture, and the strategic use of ecosystems. Four major contrasts stand out.

5.4.1 A. Strategic value capture vs. early value leakage

A central distinction lies in how SMEs manage value capture along their OI journey. More successful SMEs tend to start with internal exploitation. They either develop innovations in-house or make sure that, in early stages of collaboration, their firm retains control over the outcomes—typically through ownership of the technology, customer insights, or intellectual property. Move 1 consistently appears as an entry point supporting capability building. This early value retention gives them greater flexibility in later stages to negotiate partnerships or scale their solutions, as seen in the frequent transition from internal to co- or external exploitation (e.g., OI moves 7 to 8 and 9).

In contrast, less successful SMEs are more likely to enter partnerships where value is co-exploited or even transferred to customers or complementary partners too early. This premature value sharing reduces their ability to capture returns on innovation investments, weakens their negotiating position, and often leaves them dependent on more powerful actors. The network structure of Fig. 2 makes this visible: OI move 9 (customer–external exploitation) and OI move 5 (complementor–co-exploitation) are central in the less successful SMEs' journeys, suggesting a pattern of giving up too much, too soon. Rules involving OI move 9 and OI move 5 appear frequently without prior internal phases, confirming early leakage.

5.4.2 Early-stage R&D engagement vs. reactive research partnerships

A second key difference is the ***timing*** of collaboration with R&D service providers. More successful SMEs often begin their OI journey with an engagement that gives them access to scientific or technical expertise—what we call **first-move R&D partnering** (OI move 1). This move enables them to shape their technological trajectory early on, before committing to markets, platforms, or commercialization partners. Such early engagement can seed proprietary capabilities and generate early-stage prototypes or proof-of-concept results that serve as foundations for further collaboration.

By contrast, less successful SMEs tend to involve R&D providers later in the journey, often after having already explored partnerships with customers or complementors. This reactive approach risks turning R&D into a patch to fix emerging problems, rather than a strategic input that frames the innovation journey. Furthermore, delayed R&D engagement often occurs without strong absorptive capacity (Cohen & Levinthal, 1990), limiting the SMEs' ability to internalize and exploit external knowledge.

[6] Rules 1, 2, 5, 6, 7, 8, 9, and 10 in Table 3.

Less successful SMEs also use OI move 1, but typically later in the sequence, reducing its strategic leverage.

5.4.3 Orchestrated sequencing vs. opportunistic partnering

Third, successful SMEs appear to ***sequence their OI moves more deliberately***, building on each step in a cumulative manner. They often begin with R&D partnerships, move to customer engagement, and then involve suppliers, communities, or complementary partners as needed. This structured path allows them to align technical development with user needs, and to manage the flow of knowledge and value across actors.

Less successful SMEs, on the other hand, show signs of ***opportunistic partnering***. Rather than starting with a strategic anchor (such as R&D or internal capabilities), they enter collaborations as opportunities arise—often with customers or strong complementary partners who may dominate the agenda. This can lead to fragmented journeys, where each OI move stands alone rather than contributing to a coherent innovation strategy. The absence of clear transitions between key OI moves in their network (e.g., between OI moves 1, 7, and 8/9) suggests a lack of integration across the journey. The rule structure for less successful SMEs contains more isolated two-step sequences rather than cumulative multi-step pathways, indicating less integrated sequencing rather than merely reactive partnering.

5.4.4 Internal control and adaptive flexibility vs. early dependence

Finally, more successful SMEs show an ability to ***combine control with flexibility***. By starting with internal exploitation and building outward, they can adapt their value-capture model over time—shifting from internal to co-exploitation or even external exploitation when it serves their growth goals. This is particularly evident in the iterative cycles between OI moves 1, 7, and 9, and in the dynamic use of varied partner types.

Less successful SMEs display a more static model. Their reliance on co- and external exploitation from the outset often reflects a ***lack of internal capability*** to drive the process themselves. As a result, they become more dependent on external actors, such as large customers or dominant complementary partners, and find it difficult to pivot or reconfigure their business models in response to changing conditions. Their externally anchored initiation leaves limited room to restructure value capture later.

This comparison highlights how success in OI is not just about who SMEs collaborate with—but ***when***, ***in what order***, and ***under what exploitation mode*** they engage with different partners. More successful SMEs appear to build a stronger foundation early in the OI journey, allowing them to remain in control while benefiting from a broader ecosystem over time.

6 Discussion and conclusions

Our analysis addresses the three research questions by drawing on 500 OI moves across 106 European SMEs. Together, the findings reveal distinct patterns that differentiate more successful from less successful SMEs in how they organize, sequence, and exploit their OI efforts.

6.1 Answering the research questions

First, regarding the typical combinations of partners and exploitation modes (RQ1), the findings show that more successful SMEs engage with a broader set of partners and use more varied value capture strategies. They frequently combine R&D service providers, customers, and complementary partners, and they are more inclined to experiment with communities, crowds, or even competitors. These collaborations are not limited to any one exploitation mode: successful firms combine internal, co-, and external exploitation depending on the context. By contrast, less successful SMEs rely more heavily on external or co-exploitation, particularly in collaborations with customers or complementary partners. Their tendency to let value be captured by others reflects weaker strategic control or fewer capabilities to benefit fully from OI. These patterns were visible in the comparative network analyses and the rule-based patterns derived from the data.

Second, in relation to sequencing of partner engagement (RQ2), the distinction between successful and less successful SMEs becomes even more

pronounced. More successful SMEs typically begin their OI journeys with R&D service providers, using those early-stage collaborations to develop technological assets or validate concepts. Only afterwards do they move into partnerships with customers or complementary players. This deliberate sequencing allows them to build internal momentum and strengthen their position in later collaborations. In contrast, less successful SMEs often initiate their OI activities with market partners—customers or complementary partners—before involving R&D service providers. This reversal tends to produce less favorable dynamics and diminishes the strategic value of subsequent engagements with knowledge providers.

Third, the two groups also differ substantially in the sequencing of value capture strategies (RQ3). Successful SMEs tend to begin with internal exploitation—retaining control and value early on—before moving into co- or external exploitation modes. This progression allows them to negotiate from a position of strength in later stages. The journeys of less successful SMEs often start and end with external or co-exploitation, especially in partnerships with larger players. This reduces their ability to shape outcomes or capture value, often leaving them dependent on external actors. In addition, more successful SMEs show more variation and adaptive sequencing in their use of exploitation modes, reflecting stronger orchestration of their innovation strategies over time.

Our findings thus provide an integrated picture of how partner choices, sequencing of engagement, and value capture modes interact in shaping the outcomes of OI. By unpacking these dynamics, we gain deeper insight into why some SMEs manage to turn openness into strategic advantage, while others struggle to do so.

6.2 Theoretical implications

This study contributes to the broader literature on OI by reframing how we understand the organization of OI activities in SMEs. Rather than conceptualizing OI as a set of static partnerships, our findings emphasize the importance of *sequencing*—the temporal ordering of partner engagements and value capture strategies—as a critical determinant of innovation success. In doing so, we offer a dynamic and process-oriented perspective that advances the OI literature beyond earlier studies focused on the presence or absence of collaboration (Bahemia et al., 2018; Chesbrough et al., 2018; Du et al., 2025).

A central contribution lies in showing that successful SMEs adopt OI journeys that are not only partner-diverse but also strategically sequenced. Specifically, they begin their journeys with 'internal exploitation'—often following collaboration with R&D service providers—to consolidate early innovation outcomes within the firm. Only after this internal consolidation do they transition to co-exploitation and external exploitation modes. This sequence allows firms to secure initial value, build internal absorptive capacity, and strengthen their position in future partnerships. By contrast, less successful SMEs often reverse this logic, moving too quickly toward external exploitation without a stable internal foundation, thus weakening their ability to retain value from OI activities.

This temporal dimension extends the resource-based understanding of OI articulated by Chesbrough (2003) and aligns with recent calls to explore the *dynamics* of innovation ecosystems and collaborative processes (Vanhaverbeke, 2017; West & Bogers, 2017). It also provides a practical bridge to the business model literature, where the alignment between value creation and value capture mechanisms is central. Our findings suggest that business model innovation in SMEs is not a one-off structural shift but a sequential adaptation across the OI journey—moving from internal development toward more open commercialization pathways over time.

Furthermore, our work speaks directly to the literature on absorptive capacity (Cohen & Levinthal, 1990). The early-stage internal exploitation observed in successful SMEs appears to serve as a foundation for later co-creation with external actors. By first internalizing knowledge and translating it into initial offerings or prototypes, these SMEs are better positioned to absorb and leverage external input, negotiate favourable terms, and maintain control over value appropriation. This dynamic view of absorptive capacity as unfolding across time contributes to a richer understanding of how firms manage learning and collaboration in OI contexts.

We also extend existing typologies of OI partnerships (Albats et al., 2023; Brunswicker & Chesbrough, 2018; West & Sims, 2018) by emphasizing not only *who* SMEs collaborate with—e.g., customers, R&D service providers, complementary partners, communities, or crowds—but also *when* they do so and *how* they structure the value-capture mechanisms in these relationships. For instance, more successful SMEs in our study often engage strategically with communities and the crowd at specific points in the OI process, frequently combining these unconventional partnerships with internal exploitation to retain strategic control. This highlights a refined view of partner selection, in which timing, sequencing, and exploitation logic are deeply intertwined.

Finally, by mapping patterns across 500 OI moves in 106 SMEs, our study moves beyond the dominant case-based or survey-based OI research in SMEs (Audretsch et al., 2024b; Chesbrough & Brunswicker, 2015; Lee et al., 2010; Spithoven et al., 2013). It introduces a methodological approach that links OI activities into pathways—what we term *OI journeys*—offering a novel conceptual tool for studying OI as a dynamic and evolving process. This complements and extends prior work by adding a temporal logic to the field's understanding of SME collaboration behaviour.

This study thus contributes to the theoretical development of OI by showing how the sequencing of partnerships and value capture mechanisms shapes SME innovation outcomes. By integrating insights from OI, absorptive capacity, and business model innovation, we offer a more nuanced, process-based perspective on how SMEs can successfully orchestrate their OI activities over time.

6.3 Implications for practitioners

For practitioners, the findings offer some actionable guidelines for organizing OI activities. SME managers should view OI journeys as structured processes, where the timing and sequencing of moves are just as important as the choice of partners. Early-stage activities should prioritize internal exploitation, allowing SMEs to capture value and build a foundation for future collaborations. Engaging with diverse partners, such as journeys with R&D partners, customers, suppliers, complementors and even competitors can be highly successful if properly managed concerning timing and value capturing. Also, collaboration with communities and the crowd, can further enhance innovation outcomes when timed strategically within the journey.

Managers should also be mindful of the risks associated with premature external exploitation. While external partnerships can provide valuable resources and market access, their success depends on the SME's ability to retain sufficient value internally. By aligning value-capturing mechanisms with the stage of the OI journey, managers can maximize the long-term benefits of OI activities.

6.4 Limitations and future research

While this study provides valuable insights into how SMEs organize their OI activities, it has certain limitations that warrant further exploration. The dataset, drawn exclusively from European SMEs, may not fully capture regional or sectoral variations in OI practices. Future research could investigate whether the sequencing patterns identified in this study are consistent across diverse geographic regions or industries, offering a more global perspective on OI practices in SMEs.

Additionally, while our empirical approach—using Association Rule Mining (ARM)—effectively identifies patterns in OI move sequencing, it does not establish causality. This limitation suggests the need for complementary methods, such as longitudinal studies or experimental designs, to deepen our understanding of the causal mechanisms that underpin successful OI journeys. Such approaches could explore how specific decisions about partner selection and value capture directly impact innovation outcomes over time.

Another limitation concerns the timing of data collection, as all data used in this study were gathered in 2016–2017, prior to the onset of the COVID-19 pandemic. This pre-pandemic timeframe is an explicit limitation: the data do not capture any changes that occurred during or after the pandemic, and thus the findings may not fully generalize to the current (post-pandemic) context. Notably, however, recent evidence suggests that SMEs' innovation engagement has remained broadly consistent through the pandemic. For instance, the OECD (2023) notes that although temporary adjustments occurred during

the pandemic, the dominant innovation practices for SMEs, including their established modes of collaboration and openness, have largely returned to pre-COVID trajectories., indicating that the pandemic has not fundamentally altered SMEs' innovation patterns.

Finally, a limitation lies in the scope of this study, which focuses primarily on the sequencing of OI moves and their implications for value capture. Although we highlight the importance of collaboration with diverse partners, we do not explore the process of finding, selecting, or managing these partners. These aspects are critical to the success of OI journeys, as the choice of partners and the quality of the collaboration process significantly influence the outcomes of OI activities. Future research could address this gap by investigating the strategies SMEs use to identify and evaluate potential partners, negotiate partnership terms, and manage the dynamics of collaboration (Agostini & Nosella, 2019; Costa et al., 2023). This would provide a more comprehensive understanding of the relational and operational dimensions of OI.

Furthermore, as digital transformation reshapes the innovation landscape, future studies could examine the role of digital platforms and tools in enabling SMEs to organize and sequence their OI activities. Digital technologies may influence how SMEs identify and engage with partners, as well as how they manage value capture across different stages of their OI journeys. Exploring these dynamics would provide valuable insights for both scholars and practitioners, particularly in understanding how digital solutions can enhance the efficiency and effectiveness of OI practices.

Finally, while this study examines OI move sequencing, future research, based on in depth analysis of OI practices, could expand on how the interplay between different types of partners and their roles in OI evolve over time. Such research could enrich the theoretical understanding of partner dynamics in OI journeys and provide actionable insights for SMEs seeking to optimize their collaboration strategies.

This study sheds light on how SMEs organize their OI activities as dynamic sequences of interconnected OI moves. By focusing on the timing and sequencing of these OI moves and their associated value-capturing mechanisms, we provide new insights into the pathways that lead to innovation success. The findings emphasize the importance of combining diverse partnerships with strategic value capture and highlight the risks of premature external exploitation. By linking these insights to the broader OI literature, this study offers a comprehensive framework for understanding the dynamics of SME innovation and helps practitioners with actionable strategies for navigating the complexities of OI journeys.

Author contributions All authors contributed significantly to the conception, design, execution, and interpretation of this research. All authors have reviewed and approved the final version of the manuscript and take full responsibility for its content.

Funding Open access funding provided by HEAL-Link Greece. This research is based on data collected by the INSPIRE project (H2020 project under grant agreement No 691440) funded by the European Commission. The authors would like to thank the following.

Data availability The data supporting the findings of this study are available from the corresponding author upon request.

Declarations

Ethical This study was conducted in accordance with the ethical guidelines of the authors' respective institutions.

Conflict of interest The authors declare that they have no conflict of interest regarding the publication of this article.

Annex 1

Table 6 Data collected

Region	# of countries	# of SMEs	# of OI Moves
Eastern Europe	4	16 (15.1%)	72 (14.4%)
France & Germany	2	15 (14.2%)	58 (11.6%)
Scandinavia	4	21 (19.8%)	114 (22.8%)
Southern Europe	3	19 (17.9%)	99 (19.8%)
Small Developed Countries	4	14 (13.2%)	61 (12.2%)
UK & Ireland	2	21 (19.8%)	96 (19.2%)
TOTAL	**19**	**106 (100%)**	**500 (100%)**

Table 7 Technological intensity, sector, size and life-cycle stage characteristics of the sample

	Tech Intensity		Sector		Size			Life-cycle stage			
	High-Tech	Low-Medium Technology	Manufacturing	Services	Micro	Small	Medium	Start-up	Scale-up	Established	Renewal
# of SMEs	68 (64.1%)	38 (35.9%)	66 (62.3%)	40 (37.7%)	28 (26.4%)	52 (49.1%)	26 (24.5%)	35 (33%)	11 (10.4%)	40 (37.7%)	20 (18.9%)
# of OI Moves	311 (62.2%)	189 (37.8%)	311 (62.2%)	189 (37.8%)	128 (25.6%)	245 (49%)	127 (25.4%)	150 (30%)	53 (10.6%)	204 (40.8%)	93(18.6%)

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