R&D MANAGEMENT

The effects of entrepreneurial ecosystems, knowledge management capabilities, and knowledge spillovers on international open innovation

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While there is a large body of literature on the benefits of open innovation, little is known about the knowledge flows and the interrelationship of the purposeful and serendipitous spillover of knowledge flows that deliver value from international open innovation (IOI) collaborations. This study examines these knowledge flows occurring from IOI and the extent to which the entrepreneurial ecosystem (EE) context, knowledge management (KM) capabilities of the firm, and knowledge spillovers (KS), nurture IOI engagement. A quantitative study is adopted where data on 98,809 firms from 15 European Union countries to empirically tested a proposed model through multiple linear regressions of logit models. The results highlight the positive effect of KS on IOI engagement, and the positive mediating effect of KM capability on the relationship between KS and IOI. Additionally, the results show a positive moderating effect of the EE on the relationship between the firm's KM capability and IOI engagement. Additionally, the findings emphasize the beneficial nature of the EE on nurturing KM capabilities within firms located in the ecosystem and its impact on nurturing KS within the network.

1. Introduction

Innovation is the application of knowledge for value creation (O'Sullivan and Dooley, 2008). Historically, this knowledge for innovation was sources from resources within the individual firm, but due to factors such as innovation complexity, cost, speed to market, background IP access and other issues, modern innovation management is increasingly reliant on harnessing distributed knowledge and related capabilities, external of their boundaries (Chesbrough, 2003; Enkel and Heil, 2014; Dooley et al., 2017). This transition from a closed to more open paradigm of innovations is resulting in new practices and capabilities to leverage this knowledge and is highlighting the interconnection between the theoretical fields of innovation management, knowledge management (KM) (including knowledge spillover (KS)) and entrepreneurial ecosystems (EE).

Within an EE, cooperation agreements occur between its stakeholders to assist value creation within EE stakeholder nodes (Adner, 2006). Effective EE establish a structural dynamic and support between heterogeneous partners within the system that nurtures competitive advantage and development (Spigel, 2017; Spigel and Harrison, 2018; Audretsch and Link, 2019). Thus, the EE is both an important facilitator of innovation and identifier of entrepreneurial opportunities within knowledge-based societies (Link and Sarala, 2019) occurring through knowledge exchange and synthesis. Examining innovation performance, previous research (Spigel, 2017; Chen et al., 2020) has concluded that firms' innovation performance is influenced by the quality of its EE context, due to knowledge flows relating to access to human and financial capital, presence of networks and mentors, proximity to university and other support services, accessible market, suitable institutional environment, and government policy. Within social network collaborations, Gubbins and Dooley (2013) emphasized the connection between KM and the innovation process, highlighting the multiple phases of the KM process that must be effectively managed to support innovation alignment. Within the EE system, there are two types of knowledge flows advantageous for innovation: (1) purposeful knowledge flows governed by structured agreement, with intended outcomes, and (2) serendipitous, emergent knowledge flows, emerging both from within the purposeful collaborations and also the wider EE, that 'spillover' between network nodes during ecosystem activity.

Academic researchers have striven to better understand the connection between the impact that KS have on innovation and economic growth (Arrow, 1962; De Bondt, 1997; Fernandes and Ferreira, 2013), with Frenken et al. (2007) identifying that different types of agglomeration economies arise because of such advantageous KS. Since valuable knowledge is often tacit in nature, then sharing can be problematic, due to the 'stickiness' of its embedded nature in the host organization (Dooley and Kirk, 2007). Geographic proximity between organizations and the KS phenomenon enhances relationship (Triguero and Fernández, 2018) and nurtures more effective exchange and capture of this tacit knowledge for innovation outcome (O'Sullivan and Dooley, 2008; Dooley and Gubbins, 2019). In this sense, the literature on the relationship between KS and innovation, opens the debate regarding how this knowledge spillover effect is created (Audretsch and Feldman, 2004) and how firms can harness its potential, especially as networks become more international and underpinned with weaker ties.

An established and vibrant EE possesses attributes that can create an enabling environment for innovative ventures, that nurture symbiosis between the ecosystem (i.e., social, cultural, and material attributes of EE) and the entrepreneurial actors that co-habit the ecosystem (Mason and Brown, 2014; Stam, 2015; Chen et al., 2020). Research has highlighted the positive regional impact of KS within EE, resulting from foreign direct investment, R&D licensing, cross-border mobility of knowledge workers (Dai and Liu, 2009; Filatotchev et al., 2009; Schøtt, 2018) and knowledge sharing practices of international entrepreneurs (Liu et al., 2010; Filatotchev et al., 2011) that enrich the novel knowledge available within the ecosystem for synthesis. In breaking the boundary between a firm and its EE with respect to innovation, research has highlighted the potential for individual firms to overcome innovation constraints of scale (Narula, 2004; Hervas-Oliver et al., 2021) through leverage of synergistic resources of external entities, and transitioning towards a more opportunity-rich, open innovation (OI) paradigm.

OI paradigm (Chesbrough, 2003) adoption is the leverage by firms of purposeful knowledge inflows and outflows to accelerate internal innovation and expand markets adopting innovation outputs (Chesbrough and Bogers, 2014). The OI paradigm not only recognizes the synergistic potential of the external EE for resource-constrained innovative firms but also the importance of internal KM capabilities necessary for the focal firm to absorb the advantageous external knowledge and manage inward-out knowledge flows (Barrett et al., 2021). While the effectiveness of knowledge flow capture can be negatively impacted by geographic distance, the innovative potential of OI increases as collaborations

become increasingly internationalized. International open innovation (IOI) is advantageous for leveraging firms' innovative capabilities (Cronin et al., 2003; Fu et al., 2022), not only providing access to a larger number of knowledge sources but also because the increased geographic and cognitive distance between nodes offers greater potential for access to non-redundant knowledge for learning (Gubbins and Dooley, 2013) and subsequent innovation application. However, as distance increases, the potential of knowledge flow (purposeful and spillover) between IOI collaborators can be impeded by challenges such as cultural, language, time-zone, legal differences, trust, and operational approaches across network nodes (Dooley et al., 2016).

Despite existing research, the KM conditions for firms to enhance innovation performance within such IOI collaborations, remains poorly understood. Therefore, more research is needed to investigate these KM factors that motivate or curtail firms' engagement in IOI (Vanhaverbeke et al., 2014; West and Bogers, 2014) so that innovation performance can be optimized, and the wider EE developed, to provide support.

The review of past literature highlights both the importance and complexity of the area and that diverse authors have studied the relationship between EE, KM, KS and IOI separately. Yet, we have not found any investigation that studies this relationship, with all constructs simulanteously, to gain a deeper understanding of the interrelationships and synergies. Through the lens provided by the literature on EE, KM and KS, our research seeks to examine the effects of the constructs on the collaborative IOI engagement of companies and address the research question of: *What is the relationship between KS, KM capacity and EE in IOI?*

Exploring this question through a quantitative based analysis of the Community Innovation Survey (CIS) data, the key variables relative to IOI are modeled by linear multiple regression and logit models. From analysis, the research makes three contributions. First, this study builds on recent work, combining knowledge-based theories and IOI. Previous studies (Dooley and Kirk, 2007; O'Sullivan and Dooley, 2008; Triguero and Fernández, 2018; Dooley and Gubbins, 2019) have focused on the use of some of these theories but in an individual way, without considering their combination and interrelationship. To address this gap, this study examines the effects of EE, KM capabilities, and KS on IOI.

Second, in contrast to previous studies that focus on single, discrete aspects of EE, in this study we explore the relevance of EE and KM for achieving better performance of IOI, effectively showing that KM has a positive impact on IOI. Based on the results, we found that KM capabilities have a positive effect between serendipitous spillover of knowledge (SSK) and IOI and that EE positively moderates the relationship between SSK and IOI.

Finally, and while there is a large amount of literature on the benefits of open innovation, little is known about the knowledge flows and the interrelationship of intentional and serendipitous spillover of knowledge flows that bring value from IOI collaborations. Through an KS approach, this study provides detailed and in-depth insight into how EE provides the ideal habitat for KM capabilities and IOI collaborations to be nurtured and developed.

2. Theoretical underpinning

An entrepreneurial ecosystem (EE) is an intentional community of economic actors that co-evolve to create value and leverage capacity through collective entrepreneurial action at its core (Brown and Mason, 2017; Carayannis et al., 2017; Johnson et al., 2022). Thus, the main focus of EE is on interactive activities related to resource allocation, developing, functioning, and creating opportunities among entrepreneurs and other actors to establish a broader ecosystem (Chen et al., 2020). The EE approach highlights the importance of entrepreneurship, which is seen as a source of innovation, growth and economic development (Isenberg, 2010; Stam, 2015; Raposo et al., 2022). Yi et al. (2021) argued that EE are not an automatic process since it usually emerges in places with an established knowledge base that employs significant numbers of scientists and engineers (Mason and Brown, 2014).

Proximity to universities, R&D labs and intermediaries are seen as enablers for the emergence of EE because they are major contributors to the advancement of knowledge, scientific discoveries, and technological advances that both attract and produce talent, and in turn, this talent introduces new knowledge to the ecosystem and may become entrepreneurs that will drive future innovation and EE development (Pustovrh et al., 2019). In this sense, Spigel (2017) postulated that the attributes of EE create a favorable environment for innovation-based ventures and translation of research to commercial value.

In terms of innovation strategy, firms primarily have two key orientations: technology leadership and market expansion. Technology leadership-oriented innovations are characterized by high knowledge intensity input, to advance the prospective output of novel science-based technologies (Meyer-Krahmer and Schmoch, 1998).

Consequently, innovative firms pursuing technology leadership ambitions will proactively in seek out and acquire knowledge that enables them to advance their technology and frequently collaborate with suppliers and other organizations, possessing complementary knowledge inputs, to overcome constraints in their internal innovation process (Cooper, 1984; Chesbrough, 2003; Enkel and Heil, 2014; Dooley et al., 2016).

A firm's market orientation and success in dominating markets, is closely related to the innovation processes of its domestic and international competitors (Robinson Jr. and Pearce, 1988; Gatignon et al., 1989) and alignment of its value proposition offering with market needs. The greater the geographic distance to international markets then the greater the risk of structural holes (Burt, 2004) in its knowledge concerning consumer preferences, competitor actions and emerging trends of that particular market. Engaging with organizations in other geographic areas (Narula, 2004) can nurture and stimulate an organization's innovation process by exposing firms to new yet complementary capabilities of collaboration partners. Thus, the second orientation of innovative firms is to advance market expansion ambitions for their technological innovations and such firms seek out knowledge relevant to market structure and entry (Aboulnasr et al., 2008).

Baum et al. (2003) highlighted that organizations involved with multiple types of collaborative ties are considered more innovative than organizations relying on one type of relational tie. Substantial risks are associated with international cooperation compared to domestic collaboration, but international collaboration can also provide access to novel technologies and rich local knowledge of distant markets that facilitate innovation efforts. Thus, there are competitive motives for firms to widen the international scope of their OI collaborations to engage in IOI. Resonating with Nooteboom et al. (2007) concept of optimal cognitive distance and absorptive capacity for learning, the increased cultural and knowledge diversity of international collaborators can be an impediment to knowledge synthesis. Yet, where the necessary KM capabilities are present between collaborating nodes, then the knowledge flows from international collaboration can lead to more novel innovations due to access to 'non-redundant' knowledge for learning and application (Dooley et al., 2016; Chen et al., 2020). Thus, the richness and breadth of the EE is crucial in providing a network of contacts, both within and external to the existing EE boundaries, for innovation collaborations, both domestic and international.

The Knowledge-Based View (KBV) (Grant, 1996b), an extension of the RBV (Barney, 1991), offers organizations strategies for gaining competitive advantage by harnessing the knowledge potential of their human resources to achieve organizational outcomes. Knowledge as a unique strategic resource is at the core of KBV and views the organization as a dynamic entity that continuously evolves through the production and use of knowledge (Spender, 1996). Theory suggests that knowledge varies by organization and the value of knowledge is generally associated with desired organizational outcomes (Grant, 1996a, 1996b). Therefore, if knowledge is the key strategic resource and enables firms to compete in the dynamic environment (Spender, 1996), it becomes imperative for management to value, create and sustain knowledge sharing practices (both internally and externally) that that will underpin the desired levels of organizational performance. The leverage of externally controlled knowledge through IOI is a manifestation of this. Within the KM literature, Gold et al. (2001) defined such practice as the knowledge sharing effect, providing firms access to 'new' knowledge, often without needing to pay for the market value of that knowledge due to established relationships (Acs et al., 2002; Audretsch and Lehmann, 2005). As EE's develop and mature, they not only promote the knowledge sharing effect between organizations but also enhance the KM capabilities within these entities that nurture the knowledge process for value creation. These combined components (EE and KM) contribute to an organization's capability to search, capture, and articulate, contextualize, apply, evaluate, support and re-innovate (Gubbins and Dooley, 2013) the knowledge flows, both intended and serendipitous, that emerge from IOI collaborations and, improve the innovation performance of organizations (Yi et al., 2021; Fu et al., 2022).

2.1. Hypothesis development

2.1.1. Relationship of serendipitous spillover of knowledge (SSK) and IOI

A fundamental assumption of KBV (Grant, 1996b) is that it considers knowledge as a firm's most important intangible strategic resource. KBV advocates the importance of the creation and acquisition, the processing, storage, and application of knowledge (Grant, 1996b). The application and use of knowledge to create value and achieve superior performance depend on four attributes: valuable, rare, and difficult to imitate and replace (Barney, 1991). Thus, external knowledge advantageous for innovation will

differ dependent on the context and requirements of the absorbing entity.

Knowledge is purposefully sought out by firms, where it is complementary to existing internal knowledge, but knowledge spillover (KS) will occur also and plays an important role in nurturing the innovation process. KS occurs due to ongoing interaction of people and business, both within collaborations and more general interactions within the wider EE. KS occurs when unintended acquisition of knowledge from one economic agent influences the outcomes of other economic agents (Fu et al., 2022). This serendipitous acquisition of knowledge contributed to learning and the internal knowledge store available for later exploitation. In this sense, the vibrancy of EE in terms of knowledge-rich actors, knowledge sharing disposition and entrepreneurial zeal influences the level of KS and effect will be greater, the more abundant and interactive the knowledge exchange is within the system (Audretsch and Lehmann, 2005).

For large, well-resourced firms, the knowledge source of innovation often comes from their R&D investments and significant human capital that endogenously creates new knowledge and innovative outputs (Yi et al., 2021; Fu et al., 2022). However, the modern innovation context is one where innovation has become increasingly complex and expensive, with a high degree of turbulent in markets (Tidd and Bessant, 2020). While innovation may be a challenge for large firms, for smaller ones, this challenge is exponential and curtailing (Jenkins, 2006; Besser, 2012) due to scale of resources. Modern innovation practice is shifting from knowledge with a locus within individual firms to one within *networks of learning* (Powell et al., 1996), for all companies (large and SME). Thus, OI emerges and allows purposeful knowledge inputs and outputs to accelerate internal innovation capability and expand markets adoption opportunities for the innovation (Chesbrough, 2003).

IOI that traverses national borders can enable firms address important global challenges and fundamental scientific issues beyond internal constraints (Cronin et al., 2003). In this regard, firms can access external knowledge in two ways: (i) firms can engage in intentional knowledge exchange with other organizations through knowledge exchange agreements; (ii) firms access knowledge through unintentional information exchange; that is, through the KS mechanism (Yi et al., 2021; Germain et al., 2022). It is through these two channels of knowledge flow that synthesis is created with internal knowledge of the focal firm and IOI collaborations are validated. While both knowledge flows are important sources of innovation, the KS channel is less understood due to its unstructured nature and, within IOI of high geographic distance, such beneficial KS may be more difficult to harness. Thus, to test the impact of KS, the research hypothesis that;

H1 Serendipitous spillover of knowledge (SSK) has a positive impact on firms' IOI collaboration.

2.1.2. *The mediating role of purposeful knowledge exchange (PKE)*

According Kumar and Leonard (2012), knowledge exchange or peer-to-peer learning is the KM capability to share, replicate, and expand knowledge. KM capability is an approach that involves more actively leveraging knowledge and expertise to create value and improve firm performance (Gold et al., 2001). Effective KM facilitates the exchange of knowledge required by the innovation process and improves the performance of that same firm through developing new insights and capabilities (Chen and Huang, 2009).

KM capability is thus seen as a process involving the creation, transfer, integration, and application of knowledge (Alavi and Leidner, 2001) to support the purposeful acquiring of specific knowledge and the synthesis of the knowledge spillover effect from unstructured knowledge sharing among individuals (Nonaka and Takeuchi, 1995). Given that purposeful knowledge flow is more structured, occurring through explicit collaboration agreement, then the process is better understood and the management capabilities necessary to optimize desired outcomes developed. However, the occurrence of knowledge spillover is not an automatic process (Liu et al., 2010; Filatotchev et al., 2011) and due to its emergent nature, the process and supporting capabilities are less understood.

To optimize benefit from both knowledge flows for the innovation process, firms must continuously develop their KM capabilities to internalize both purposeful sourced and spillover knowledge with existing internal knowledge for learning and skills development (Liu et al., 2005; Kloosterman, 2008). Engagement in IOI for purposeful knowledge exchange increases the social network breadth of the firm and consequently increases the scope for KS to occur, during in the process of acquiring the intentional knowledge that drove IOI formation. As firms develop their knowledge capabilities of absorption and exploitation, then the likely value creation from all forms of external knowledge increases, including spillover (Chen and Huang, 2009) and stimulate IOI. Thus, the potential positive influence of established

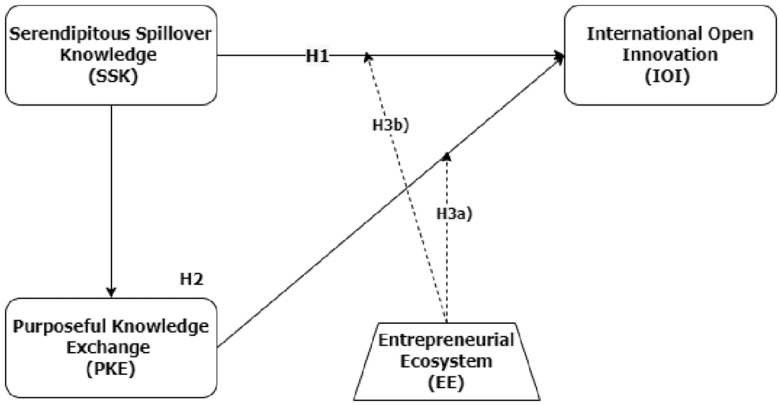

Figure 1. Research model.

KM capabilities developed within the firm, the research hypothesis that;

H2 Purposeful knowledge exchange (PKE) mediates the impact of serendipitous spillover of knowledge on IOI collaboration.

2.1.3. *The moderation role of the entrepreneurial ecosystem on serendipitous spillover of knowledge and purposeful' knowledge exchange*

The EE is a dynamic system where its composition and relationships and opportunities are constantly evolving, as is typical in biological ecosystems (Wright and Stigliani, 2012; Autio et al., 2014; Hayter, 2016). Yi et al. (2021) argues that the relationship between firms' KM capability and innovation performance will depend on EE conditions. EE is a set of interdependent actors and factors coordinated to enable productive entrepreneurship (Stam, 2015). The action of a firm in isolation may not be sufficient to achieve high innovation performance and thus contextual factors may impact its innovation success (Acs et al., 2002; Mason and Brown, 2014).

Equally, the effectiveness of organizational capabilities, such as KM, are influenced by the institutional environment (e.g., the formal legal environment and informal cultural support) within which they exist (Peng and York, 2001; Peng et al., 2008). When the EE is well established, it provides an enabling environment that provides firms with greater opportunities to develop their KM capabilities (Yi et al., 2021; Raposo et al., 2022) since interorganizational interaction is looked on favorably by the community. In this sense, EE can support the KM process in creating routines and policies to guide how to effectively manage the external knowledge accessible through IOI (Bendickson et al., 2021).

Noelia and Rosalia (2020) identified that different actors in an EE (e.g., suppliers, universities, and potential cooperation partners) can reduce the obstacles that firms face when developing innovations by nurturing capabilities to encourage knowledge exchange. The presence of such capabilities not only supports purposeful exchange that the focal firm intentionally manages but also enhances their awareness of knowledge spillover flows that they can harness if appropriate.

Thus, an EE provides the necessary infrastructure to support the KM capability development of firms for innovation (Yi et al., 2021). In the case of IOI, the existence of a well-structured EE, increases linkages to international partners possessing proprietary knowledge and resources and provides opportunities and support systems for firms to innovate faster and efficiently (Chen et al., 2020). Ultimately, the presence of an EE helps entrepreneurial nodes establish their IOI and develop the internal and external capabilities to harness knowledge flows for improved innovation performance (Singh et al., 2021; Fu et al., 2022). Thus, given the connection between EE and the knowledge flows supporting innovation, the research hypothesizes that:

H3a EE moderate the impact of purposeful' knowledge exchange (PKE) on IOI collaboration.

H3b EE moderate the impact of serendipitous spillover of knowledge (SSK) on IOI collaboration.

The research model and proposed hypotheses is shown in Figure 1.

3. Methodology

3.1. *Data*

The empirical analysis is underpinned by the Community Innovation Survey (CIS). The target population of the CIS is the total population of

enterprises in NACE Rev. 2 sections A to M with more than ten employees. The survey excludes NACE Rev. 2 industries in sections O to U consisting of public administration, education, health and social work, arts, entertainment and recreation, other service activities (professional organizations and personal services), households, and extraterritorial bodies.

The data included in this study refer to the latest available CIS and include those countries for which micro data are available or that the anonymization process does not invalidate the use of these data. In each country, the sample selection was carried out through random sampling, based on the official statistical and updated records of the companies in the country. For stratification of the sample, data were used regarding the activity classification (NACE) and the size class of the company, according to the number of employees. Overall, data on 98,809 firms from 15 European Union countries were used.

Table 1 summarizes the main characteristics of the sample, such as the geographical location (country), size and activity sector of the firms.

Table 1. Sample characteristics

	N	%
Country		
Bulgaria	14,255	14.4%
Cyprus	1,346	1.4%
Czech Republic	5,198	5.3%
Germany	6,282	6.4%
Estonia	1,760	1.8%
Greece	2,507	2.5%
Spain	30,333	30.7%
Croatia	3,265	3.3%
Hungary	6,817	6.9%
Lithuania	2,421	2.5%
Latvia	1,501	1.5%
Norway	5,045	5.1%
Portugal	7,083	7.2%
Romania	8,206	8.3%
Slovakia	2,790	2.8%
Industry		
Manufacturing	37,846	38.3%
Electricity and Water supply	4,084	4.1%
Construction	2,906	2.9%
Wholesale and retail trade	22,940	23.2%
Services	31,033	31.4%
Size		
SME	88,720	89.8%
LE	10,089	10.2%

N = total no. of companies.

3.2. Variables

3.2.1. Dependent variables: international open innovation

The dataset provides information about a firm's collaboration with seven different partners (Other enterprises within enterprise group, Suppliers of equipment, Clients or customers from the private sector, Clients or customers from the public sector, Competitors or other enterprises, Consultants and commercial labs, Universities, Government, public or private research institutes) in four different geographic locations, including (1) EU/EFTA/EU-CC, (2) US, (3) China or India; and (4) other countries.

In this study, a firm's degree of openness defined by Fu et al. (2022) was used as the ratio of the total number of international collaborations (by type and geographic location) to the total number of all domestic and foreign collaborations.

Thus, IOI of a firm is calculated using the following index:

$$\mathrm{IOI}_i = \frac{\sum_{i=1}^{n} \mathrm{ICO}_i}{\sum_{i=1}^{n} \mathrm{CO}_i}$$

where IOI is the degree of international openness in innovation, ICO is international collaboration and CO is collaboration, *i* refers to firm *i*, and *n* is the number of collaborations by partner type and geographic location. The IOI index takes values from 0 (no international collaborations) to 1 (international collaborations only) as a ratio of openness to international collaborations.

Admittedly, while this measurement has the advantage of reflecting the scope and variety of a firm's international openness in innovation, it also has some limitations in that it does not reflect the exact number of international innovation collaborations with which a firm can engage.

3.3. Independent variable

3.3.1. Serendipitous spillover of knowledge (SSK)

To measure SSK, the approach of Yi et al. (2021) was employed with two dimensions – explicit knowledge spillovers (EKS) and tacit knowledge spillovers (TKS). To measure EKS, the following four variables were used: (i) Engagement in intramural R&D (No *vs* Yes); (ii) Engagement in acquisition of machinery (No *vs* Yes); (iii) Expenditures in intramural R&D (ratio/turnover); and (iv) Expenditures in acquisition of machinery (ratio/turnover).

To measure TKS, the variables were used: (i) Engagement in extramural R&D; (ii) Engagement in acquisition of external knowledge; (iii) Expenditures

in extramural R&D (ratio/turnover); and (iv) Expenditures in acquisition of external knowledge (ratio /turnover).

Composite indices were calculated for each dimension, EKS and TKS, and the overall value.

3.3.2. *Mediator variable: purposeful knowledge exchange (PKE)*

To measure as PKE capabilities linked to the innovation process three variables were used: (i) new business practices for organizing procedures (No *vs* Yes); (ii) New methods of organizing work responsibilities and decision making (No *vs* Yes); and (iii) New methods of organizing external relations, and a composite index was calculated (Yi et al., 2021; Fu et al., 2022).

3.3.3. *Moderator variable: engagement in EE*

Regarding the company's involvement in EE, we used the same variables that Raposo et al. (2022) used in their study: (i) Cooperation arrangements for product and/or process innovation with Suppliers (No; Yes); (ii) Clients or customers (No; Yes); (iii) Universities (No; Yes); and (iv) Government, public or private research institutes (No; Yes). To measure the EE a composite index was calculated.

All items included in independent, mediator and moderator constructs are presented in Appendix, Table A1.

3.3.4. *Control variables*

The variables used in the analysis were economic activity, size and turnover (thousands of euros). Dummy variables were created for each economic activity. The CIS survey is applied in several countries, so we cannot just assume that the characteristics of individuals are not independent over the country. We performed all estimations using cluster standard errors at the country level, with jackknife procedure, to account for potential arbitrary dependence across and within countries.

3.4. *Method*

Before evaluating the hypotheses, we conducted confirmatory factor analyses (CFA) to assess the reliability and validity of each construct. Composite reliability (CR) ranged from 0.75 to 0.92 – above 0.7. Convergent validity was also obtained as average variance extracted (AVE) for each scale ranged from 0.558 to 0.732 – above 0.5. Construct validity was estimated based on comparing the AVE with the correlations between the constructs, concluding that the scales measure distinct constructs and test the proposed hypotheses (Table 2). For each construct, a composite index between 0 and 1 was calculated based on the CFA.

To test hypothesis H1 and the moderating effects (H3), we use Heckman's two-stage model (see Appendix, Table A2) to determine the estimates in models where the dependent variable is IOI, as only firms that decided to engage in cooperation processes report the number of collaborations and the number of international collaborations. An initial binary model estimates the probability of a firm undertaking collaboration in the first equation. A second-stage Ordinary Least Square (OLS) equation, of which IOI is the dependent variable, contains a selection correction term derived from the first equation and captures the determinants of IOI. The rho statistic tests the correlation between the error terms in the first and second stage equations and was significant in all equations. To evaluate H3, an interaction variable corresponding to the product of the PKE variable with EE was calculated. To test H1, two multiple linear regressions were estimated using OLS. In all models, we used as control variables country (14 dummy variables), economic activity (4 dummy variables), being a Large Enterprises (LE) (dummy) and turnover (thousands of euros).

4. Results

4.1. *Direct effect of SSK on IOI*

Table 3 provides the means, standard deviations, and correlation coefficients of the main variables studied. Based on the results of Table 3, it is found

Table 2. Construct inter-correlations for the confirmatory factor analysis model

	Range	Mean	SD	AVE	CR	Alpha	1	2	3	4	5
(1) EKS	0–1	0.17	0.31	0.690	0.852	0.801	**0.831**				
(2) TKS	0–1	0.07	0.18	0.599	0.838	0.720	.419**	**0.774**			
(3) SSK	0–1	0.12	0.23	0.624	0.824	0.798	.662**	.482**	**0.790**		
(4) PKE	0–1	0.15	0.30	0.649	0.876	0.810	.382**	.323**	.387**	**0.806**	
(5) EE	0–1	0.22	0.70	0.617	0.803	0.793	.411**	.418**	.512**	.311**	**0.785**

Squared root of AVE in diagonal.
**$P<0.01$.
EE, entrepreneurial ecosystems; EKS, explicit knowledge spillovers; PKE, purposeful' knowledge Exchange; SSK, serendipitous spillover of knowledge; TKS, tacit knowledge spillovers.

Table 3. The effect of SSK on IOI

	B (SE)	*B* (SE)
Turnover	–0.03 (0.09)	–0.04 (0.09)
Electricity and water supply	–0.13 (0.05)**	–0.14 (0.05)*
Construction	–0.19 (0.05)**	–0.20 (0.06)**
Wholesale and retail trade	–0.07 (0.02)**	–0.07 (0.03)*
Services	–0.05 (0.01)***	–0.04 (0.01)***
Large enterprises	0.22 (0.07)**	0.19 (0.02)***
EKS	0.23 (0.08)**	
TKS	0.06 (0.02)**	
SSK		0.08 (0.03)*
Constant	–0.74 (0.69)	–0.33 (0.35)

Estimated results of the first stage of the Heckman model are reported in the Appendix.
**$P<0.01$, **$P<0.05$, *$P<0.1$.
EKS, explicit knowledge spillovers; SE, standard error; SSK, serendipitous spillover of knowledge; TKS, tacit knowledge spillovers.

Table 4. The indirect effect (coefficients and SE) of SSK on IOI through PKE

	PKE	IOI[1]
Turnover	–0.08 (0.02)**	–0.03 (0.02)
Electricity and Water supply	0.72 (0.61)	–0.19 (0.03)***
Construction	1.19 (1.42)	–0.2 (0.04)***
Wholesale and retail trade	0.67 (0.23)	–0.08 (0.03)**
Services	2.35 (0.56)	–0.05 (0.02)*
Large Enterprises	9.06 (1.30)***	0.12 (0.03)***
SSK	0.49 (0.13)***	0.12 (0.05)*
PKE		0.11 (0.03)***
Constant	6.84 (0.25)***	0.28 (0.09)**
Indirect effect of SSK on IOI		0.05 (0.02)**

[1]Estimated results of the Heckman model's first stage are reported in the Appendix (Sobel test).
***$P<0.01$, **$P<0.05$, *$P<0.1$.
IOI, international open innovation; PKE, purposeful' knowledge exchange; SSK, serendipitous spillover of knowledge.

that SSK is positively related to IOI (B = 0.08, $P<0.05$).

In addition, we tested the effect of EKS and TKS separately and found that both have a significant and positive effect on innovation performance, supporting hypothesis H1 (B = 0.23, $P<0.01$ and B = 0.06, $P<0.01$, respectively). Our results allow us to support H1: *Serendipitous spillover of knowledge have a positive impact on firms' IOI collaboration*. We can conclude that SSK function as external benefits of knowledge creation, enhances firms' innovation activities (Agarwal et al., 2010; Liu et al., 2010; Filatotchev et al., 2011). Our results reinforce that SSK help IOI, because it can help companies face important global challenges, such as competition across national borders (Cronin et al., 2003) and deepen the coupling within IOI. Our results show that knowledge spillovers are important for the sustainability of endogenous growth due to their positive externalities. They translate into the promotion and diffusion of knowledge, with direct impacts at the IOI level. Through SSK, firms' access to external knowledge is crucial for their good innovative performance, especially IOI (Yi et al., 2021).

4.2. *Tests of mediation*

To evaluate the mediating effect of PKE on the relationship of SSK with IOI, we first used OLS methods to determine the impact of PKE on SSK and in a second step, we evaluated whether SKK capacity has an impact on IOI. Table 4 shows the results of the indirect effects of SSK on IOI through PKE.

SSK are found to have a significant indirect effect on IOI (0.05). Our results support hypothesis H2: *Purposeful' knowledge exchange mediating the impact of serendipitous spillover of knowledge on IOI collaboration*.

If SSK play a fundamental role in knowledge creation and opportunity recognition, then it is

fundamental that companies develop capabilities that manage them (Fernandes and Ferreira, 2013). As argued, effective knowledge management facilitates the exchange of knowledge required in the innovation process and improves the performance of innovation in firms through the development of new insights and capabilities (Gold et al., 2001; Chen and Huang, 2009).

PKE are thus essential to ensure sustained and desired levels of open innovation, especially when it takes place in an international context (Fu et al., 2022) as they underpin absorption and application of both the purposeful and spillover knowledge flows within the system.

4.3. Tests of moderation

Table 5 presents the moderating effects of EE involvement on the relationship between PKE and IOI and between SSK and IOI.

The results show that the attributes of an EE moderate the relationship between SSK and IOI. The results suggest that the interaction item between SSK and EE attributes is statistically positive (B = 0.03, $P<0.05$), and whereby the higher the involvement in EE the higher the relationship between SSK and IOI. Our results thus support hypothesis. *H3a: EE moderating the Impact of Purposeful' knowledge exchange on IOI collaboration*. We thus corroborate that an EE can promote the effectiveness of organizational capabilities such as SSK (Peng and York, 2001).

Table 5. The moderating effect (coefficients and SE) of engagement in EE on the relationship between PKE and IOI

	B (SE)
Turnover	–0.06 (0.11)
Electricity and Water supply	–0.16 (0.05)***
Construction	–0.20 (0.05)***
Wholesale and retail trade	–0.05 (0.01)***
Services	–0.04 (0.02)*
Large Enterprises	0.09 (0.04)**
SSK	0.06 (0.01)***
PKE	0.10 (0.02)***
EE	0.04 (0.01)***
PKE*EE	0.04 (0.01)**
SSK*EE	0.03 (0.01)*
Constant	0.98 (0.67)

Estimated results of the first stage of the Heckman model are reported in the Appendix.
***$P<0.01$, **$P<0.05$, *$P<0.1$.
EE, entrepreneurial ecosystems; PKE, purposeful' knowledge exchange; SSK, serendipitous spillover of knowledge.

It is also observed that the attributes of an EE moderate the relationship between PKE and IOI. The results suggest that the interaction item between PKE and EE attributes is statistically positive (B = 0.04, $P<0.01$), and whereby the higher the involvement in EE the higher the relationship between PKE and IOI. Our results thus support hypothesis *H3b: EE moderating the impact of serendipitous spillover of knowledge on IOI collaboration*. We can further reinforce that the EE provides a facilitating environment that enables firms to exercise better their PKE that promote innovation activities (Peng et al., 2008; Yi et al., 2021). Other authors argue that EE can assist IOI as it provides access to an international network of partners that helps firms innovate and innovate faster (Chen et al., 2020).

5. Discussion and implications

The main objective of this study was to explore the relationship between EE, PKE and on IOI. Therefore, we examine the mediating role of PKE capabilities in the impact of SSK on IOI collaboration and the moderating role of the EE in the impact of SSK and PKE on IOI collaboration. Based on the results, it can be concluded that the value of knowledge impacts knowledge sharing practices and influences IOI.

In addition, an appropriate context such as the existence of an EE provide a positive relationship between PKE and IOI. Thus, the seeking out, acquisition, absorption, synthesis, and application of knowledge can be considered essential factors in the competitive dynamics of the firm and encourages open innovation activities. Given that knowledge assumes a strategic level importance for the firm, then management must strive to hone their KM capabilities and network linkages within the EE to maintain competitive advantage. The theoretical and practical implications of the study will be discussed further.

5.1. Theoretical implications

Our research findings suggest an association between SSK, PKE, EE, and IOI and based on this, and we offer three key implications for theoretical development relating to the antecedents and outcomes of IOI.

First, SSK is fundamental to establishing and maintaining of an IOI (Lee et al., 2016) as it alerts the firms to new opportunities for innovation (Donate and Sánchez de Pablo, 2015) and enhances awareness of dynamic markets. Moreover, previous research argues that SSK influence both

open innovation and PKE (Lee et al., 2010; Fu et al., 2022). While PKE is the initial stimulant of IOI, reinforcing a firms existing innovation trajectory (since the firm has intentionally sought out the partnership for specific knowledge resource), the SSK that emerges unexpectedly, can challenge cognitive thinking and pivot the firm's innovation direction. In addition, when determining the value of the IOI to the focal firm, then it is value derived from SSK exploitation that often motivates continuation within the IOI, since the value of the PKE was already factored into the determination to undertake the IOI. Therefore, our research confirms that PKE and SSK both underpin IOI sustainability by contributing to value appropriation. As a result, it is beneficial for knowledge-oriented leaders to develop and encourage knowledge sharing practices that facilitate value appropriation from such knowledge (Donate and Sánchez de Pablo, 2015) to nurture IOI effectiveness. Thus, managers should be guided to support 'knowledge brokers' engaging in knowledge sharing practices across firms and be actively scanning for knowledge spillovers that will be advantageous to the firm's innovation efforts.

Second, we also find evidence that PKE capabilities have a positive effect between SSK and IOI. Like other authors, we too conclude the positive effect of this mediating relationship (Jarvenpaa and Majchrzak, 2015; Brunswicker and Chesbrough, 2018). We believe that management should develop formalized KM routines that identify and exploit SSK and consequently validate the benefit of the IOI (Brunswicker and Chesbrough, 2018). The presence of developed PKE capabilities within the firm, optimizing its value capture from IOI collaborations aligns with findings of Dooley and Gubbins (2019) that management must synthesis rather than balance the competing dialectic tensions of inter-organizational knowledge creation, such as the extent to sharing and protecting knowledge (Jarvenpaa and Majchrzak, 2015) within the network. Through experience and practice, absorptive capacity of the firm increases, together with the relational capability to deepen knowledge sharing for future value creation. SSK can also be a driver of KMC since it identifies both gaps in our capabilities and also future trends and thus provides a scanning mechanism for the RBV strategic development of the firm.

Third, we find a positive effect on the EE moderating relationship between PKE and IOI. We know from the literature that EE is increasingly viewed as advantageous, both by national innovation policies and management theories (Spigel, 2017; Pustovrh et al., 2020). Furthermore, we also found a positive moderating effect of EE on the relationship between SSK and IOI. It is argued in the literature that EE are SSK facilitators, thus helping the various innovation activities (Peng et al., 2008; Yi et al., 2021).

We are convinced that EE allow us to create a way of conceptualizing entrepreneurship more holistically, emphasizing the interactions between the various actors, such as institutions, firms, and individuals, involved in not only innovative but IOI activities (Audretsch and Belitski, 2017; Yi et al., 2021). Thus, EE determine the long-term prospects of firms' innovation and knowledge management practices since it enriches the network of knowledge nodes and nurtures a culture of collaborative knowledge sharing (both PKE and SSK) and co-creation for mutual benefit.

SSK at an organizational level is traditionally viewed as something negative, that undermines competitive advantage, but this research shows that it can be a positive and important factor in sustaining and appropriating value from IOI efforts contributing to competitive advantage. Equally, the research shows that SSK is necessary at both organizational level and at regional level (EE) and thus we need to acknowledge the role organizations as stakeholders play in nurturing the EE development so it is advantageous for moderating PKE and SSK at organizational level. A latter managerial implication of this is that managers need to be janusian/ ambidextrous in achieving synergy of knowledge flows between their organization-EE and *vice versa*. Managerial challenge in nurturing SSK to dive innovation at IOI and EE level and yet protecting it so it can appropriate value as a resource of the firm.

5.2. *Practical implications*

Our research finds that managers' commitment to the value of knowledge helps create and maintain knowledge sharing practices to increase IOI. Therefore, our research highlights three implications for practice. First, we suggest that the success of firms depends on how managers value knowledge creation and knowledge sharing, not only among organizational members but also with their national and international EE peers (Jarvenpaa and Majchrzak, 2015; Brunswicker and Chesbrough, 2018). Here PKE capabilities assume particular importance in the sense that they help companies to manage knowledge flows, whether purposeful or serendipitous and recognize their potential for competitive advantage. Therefore, we postulate that managers of firms aspiring to harness the potential of the EE, should engage with the various elements of EE and direct the focus of the organization's members' thinking

towards knowledge sharing, so that firms develop IOI processes to meet the needs of their customers (Peng et al., 2008; Yi et al., 2021). Therefore, they are better positioned to seek-out, access, absorb and apply externally sourced knowledge to validate their IOI activities.

Second, we suggest that firms' IOI practices are a strategic asset to achieve sustainable competitive advantage and enhanced organizational-level performance. (Donate and Sánchez de Pablo, 2015). Therefore, we suggest that firms strive to install functional processes and systems that support IOI to seize market opportunities and outperform their competitors (Brunswicker and Chesbrough, 2018). We further suggest that managers embrace the philosophy of innovation openness to make their companies responsive to their customers' needs and emerging technological opportunities. This corresponds with Enkel et al.'s (2011) perspective of open innovation maturity framework, where the complexity and value-potential of OI integrations increases relative to the developing management capability underpinning the firm's efforts. Thus, there is need for organizations to establish long-term commitment to adopting the OI paradigm, developing the required KMC and EE networks to underpin successful implementation of increasingly challenging IOI initiatives.

Third, EE provide the ideal habitat for both KM capabilities and IOI collaborations to develop. In this sense, we suggest that managers should initially harness the EE to advance their internal knowledge capabilities and their awareness of the knowledge expertise across the ecosystem (Brunswicker and Chesbrough, 2018). Then the firm will be in a better position to engage in broader and more diverse collaborations across the EE, at national and international level and leverage beneficial knowledge from external sources to scan for opportunities, support their innovation activities and identify emerging trajectories for future capability development. In this way, knowledge management capabilities, IOI collaborations and the wider EE, operate in synergy and create a virtuous circle of innovation, built upon the extended resource-based view of the firm.

5.3. Limitations and future research

As a rule, all studies of this nature have limitations, and this one is no exception. The fact that not all countries within the CIS have collected data on the variables studied is a limitation. Thus, there is still a way to go in the importance of collecting and processing this type of data. This shortcoming meant that we were only able to include companies from nine countries. In the future, we should analyze the context of the companies in the different countries, using other types of data, namely primary data. In addition to the analysis of other countries, the study of the influence of their context, measured through variables such as: formal and informal institutions and inequality (using the GINI coefficient) in the study of the relationship between EE, KS, KM, and IOI.

We also did not analyze differences between sectors of activity. Thus, future research can expand on this study by examining the behaviors of different sectors to assess whether there are differences between industries and suggest ways to promote knowledge and assist policy makers develop policies targeted at each specific sectoral context to support companies that have IOI practices. We also suggest that we explore how micro-level variables (e.g., trust, personality characteristics of managers and employees, employee involvement) support or obstruct firms' orientation towards an IOI in future research. Third, we use quantitative analysis, which as we know, has its own limitations. Thus, future research should use mixed methods, such as qualitative techniques to investigate what factors and conditions support IOI practices in firms.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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APPENDIX

Table A1. Items included in independent, mediated, and moderated constructs

Serendipitous spillover of knowledge

Explicit knowledge spillovers

(i) Engagement in intramural R&D (No *vs* Yes)

(ii) Engagement in acquisition of machinery (No *vs* Yes)

(iii) Expenditures in intramural R&D (ratio/turnover) and

(iv) Expenditures in acquisition of machinery (ratio/turnover)

Tacit knowledge spillovers

(i) Engagement in extramural R&D (No *vs* Yes)

(ii) Engagement in acquisition of external knowledge (No *vs* Yes)

(iii) Expenditures in extramural R&D (ratio/turnover)

(iv) Expenditures in acquisition of external knowledge (ratio/turnover)

Purposeful knowledge exchange

(i) New business practices for organizing procedures (No *vs* Yes)

(ii) New methods of organizing work responsibilities and decision making (No *vs* Yes)

(iii) New methods of organizing external relations

Entrepreneurial ecosystem

(i) Cooperation arrangements for product and/or process innovation with suppliers (No Yes)

(ii) Clients or customers (No Yes)

(iii) Universities (No Yes)

(iv) Government, public or private research institutes (No Yes)

Table A2. Stage 1 of the Heckman model: probit estimates of firms' likelihood to collaborate

	B (SE)	*B* (SE)	*B* (SE)	*B* (SE)
Turnover	0.03 (0.01)***	0.10 (0.05)*	0.03 (0.01)*	0.04 (0.01)**
Electricity and water supply	0.14 (0.06)*	0.11 (0.05)*	0.10 (0.04)**	0.01 (0.07)
Construction	−0.11 (0.05)*	−0.12 (0.05)**	−0.10 (0.05)*	−0.17 (0.05)***
Wholesale and retail trade	−0.07 (0.02)**	−0.08 (0.04)*	−0.09 (0.04)**	−0.08 (0.06)
Services	0.11 (0.03)**	0.09 (0.05)	0.01 (0.01)	0.10 (0.06)
Large enterprises	0.50 (0.10)***	0.52 (0.112)***	0.47 (0.12)***	0.76 (0.31)**
EKS	0.02 (0.00)***			
TKS	0.01 (0.00)*			
SSK		0.05 (0.01)***	0.03 (0.01)***	0.02 (0.00)***
PKE			0.02 (0.01)***	0.42 (0.17)**
EE				6.11 (2.34)**
PKE*EE				−0.02 (0.01)
SSK*EE				0.40 (0.30)
Constant	−1.96 (0.13)***	−1.89 (0.13)***	−1.96 (0.11)***	−2.56 (0.18)***

***$P<0.001$, **$P<0.01$, *$P<0.05$.