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Convergence between absorptive capacity and knowledge appropriation: A new methodology Mapping the hidden links

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ABSTRACT

This study investigates the relationship between Absorptive Capacity (AC) and Knowledge Appropriation (KA), two significant domains in technology transfer, knowledge management, and innovation. While there is an inherent connection between these fields, there remains a gap in understanding their comprehensive convergence. To address this, we reviewed 3412 AC and 368 KA articles, employing techniques such as life-cycle, changepoint, and advanced keyword analyses. We also introduced innovative methods like the H-index, CAGR, and a unique approach comparing keyword frequency over time between AC and KA, spotlighting key convergence areas: innovation, entrepreneurship, and knowledge spillover.

Our analysis revealed a parallel evolution of AC and KA, as demonstrated by their shared timelines, thematic overlaps, and mutual influences in the realm of innovation. The life-cycle analysis showed a faster evolutionary pace for AC than for KA but highlighted their shared roots in management during the late 80s. Furthermore, we identified foundational building blocks, including patents, R&D, and knowledge management, that underpin their convergence. Interestingly, some divergent areas were also pinpointed, such as the emphasis on organizational learning in AC but its absence in KA.

In summary, this study provides a clear picture of the intertwined relationship between AC and KA, presenting a refined methodology to explore convergence between academic fields, setting the stage for further research in this domain.

1. Introduction

Absorptive capacity (AC) is defined as the ability to acquire, assimilate, transform, and exploit knowledge (Cohen and Levinthal, 1990; Zahra and George, 2002) based on environmental scanning (Lane et al., 2006) and mediated by social mechanisms and strategic alliances (Todorova and Durisin, 2007).

Knowledge appropriation (KA) is defined as the "firm's ability to benefit from its resources and capabilities" (Milesi et al., 2013; Teece, 1988), generating profit from the innovation (Teece, 1986), and the protection strength depends on the depth of the appropriability (Chen and Chang, 2019).

AC and KA are strongly associated with their origins, and the main AC models have named KA as a trigger or an adverse effect for AC

(Cohen and Levinthal, 1990; Zahra and George, 2002). In addition, AC and KA are essential elements that improve innovation performance (Dedrick et al., 2010; Hervas-Oliver et al., 2011; Kokshagina et al., 2017), knowledge management-KM- (Hurmelinna-Laukkanen, 2012a; O'Dwyer and O'Flynn, 2005), and entrepreneurship and value generation (Cepeda-Carrion et al., 2017).

The specialized literature on each topic has identified the relevance of studying AC and KA in depth (Chaparro et al., 2021; Hurmelinna-Laukkanen, 2012; Sun and Zhai, 2018), recognizing, AC as a hotspot of KA (Sun and Zhai, 2018) and identifying the need to study both topics in depth. Some studies have analyzed the link between AC and KA, comparing their origin and the effects on innovation and KM (Cuéllar et al., 2022). These approaches have identified explicit connections between AC and KA but not the underlying links.

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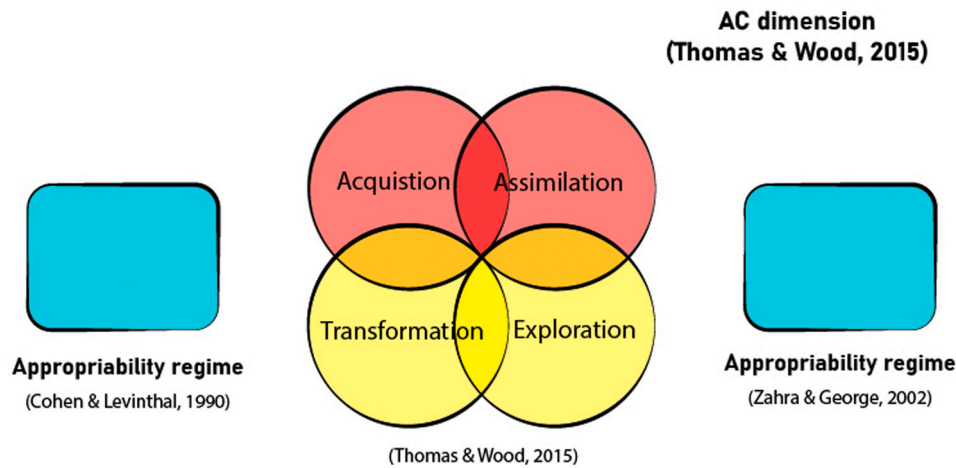


Fig. 1. Convergence between AC and KA in AC models.

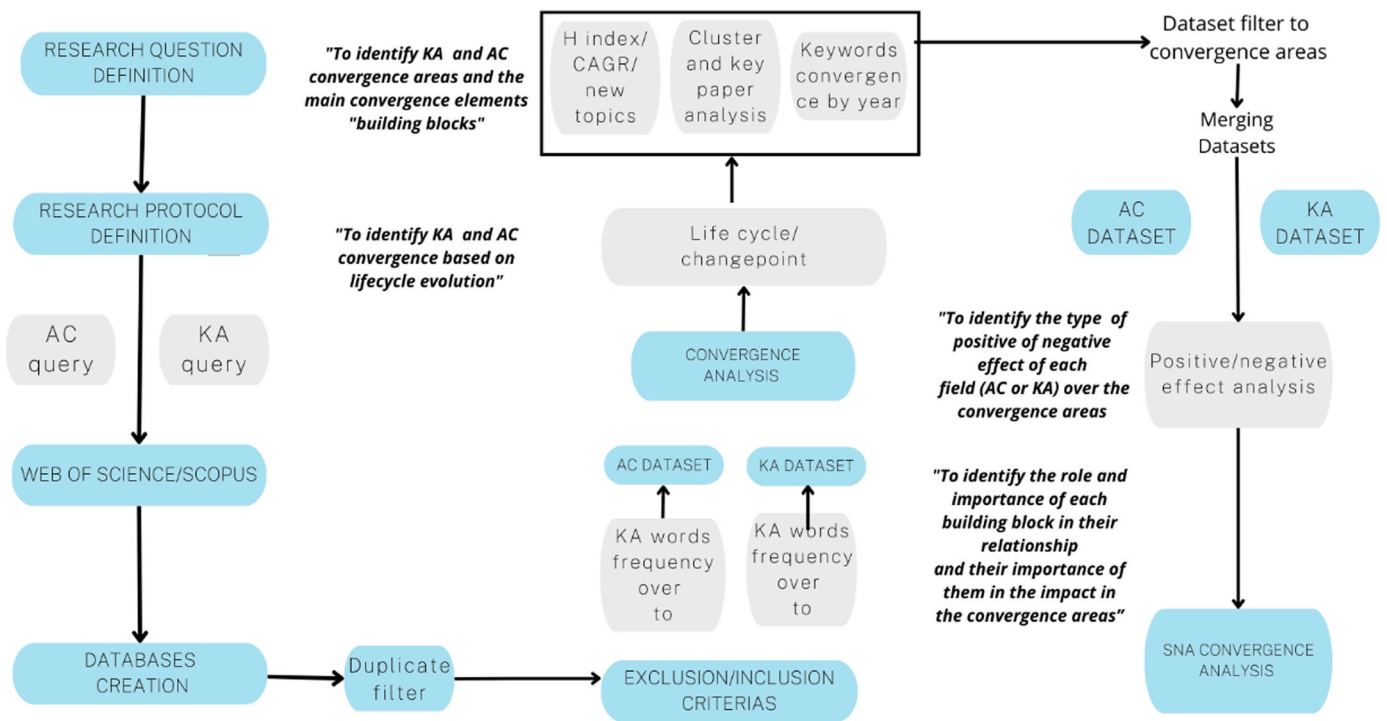


Fig. 2. Framework of analysis of our research.

Hidden links between two or more topics can be identified using convergence analysis. It was defined as "the increasing overlap between different scientific fields and is manifested through intensified cross-disciplinary scientific research" (Hacklin et al., 2021). Through this type of analysis, we can better understand the relationship between fields that may seem disconnected (Rosenberg, 1963). Convergence has mainly been applied to understand the convergence between technological fields or industries (Klarin et al., 2021), mostly based on patent data (Heo and Lee, 2019), and it is mainly used to understand the influence of further scientific development and technologies in various industries. In the management field, convergence analysis is an emerging topic.

Recognizing this gap, our purpose was to leverage convergence analysis to elucidate the nuanced relationship between AC and KA. We posited the research question: "What are the hidden links between AC

and KA, and how do they converge in the context of management studies?" This study seeks to provide clarity on this intricate interplay.

To identify the hidden links between KA and AC, we conducted a convergence analysis by comparing the evolution of both topics to identify the patterns over time. We identified the main trends in each field to distinguish the convergence of the impact in different areas. In addition, we analyzed the convergence in time to determine whether this convergence has grown. In addition, we examined the positive and negative impacts of AC and the influence of KA on the main management convergence fields to uncover convergences based on their impact. Finally, we identified other management topics that have been important to generate this convergence as essential complements building blocks.

To conduct this analysis, we performed a review based on bibliometric analysis. This paper is divided into the following sections. First,

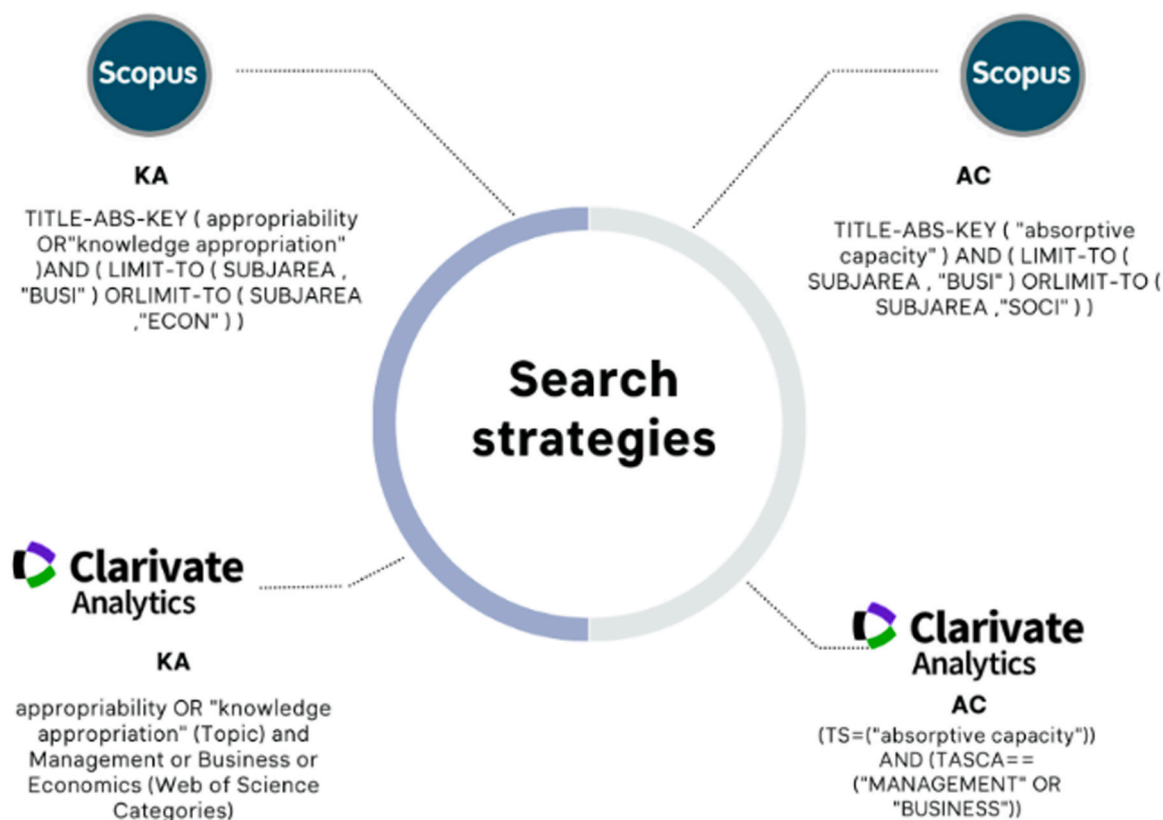


Fig. 3. Search strategies for recovering AC and KA literature.

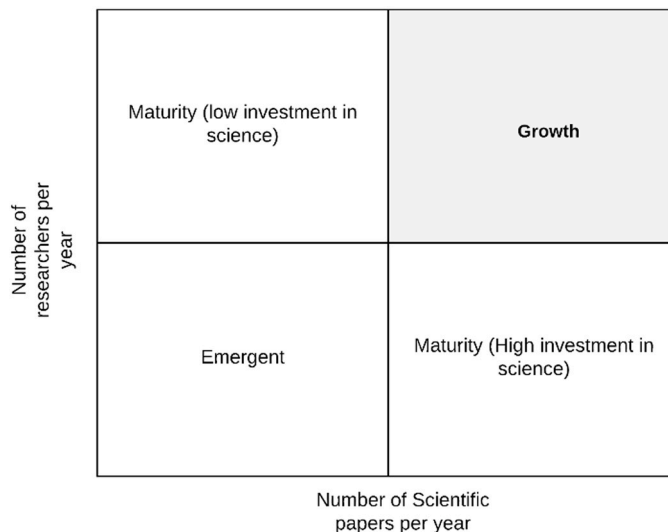


Fig. 4. Life-cycle method used in this study.

Table 1
Year convergence analysis between AC and KA.

AC Topics	KA Topics	Convergence	Divergence
Intellectual capital, patent	Patent, knowledge sharing	Intellectual capital	Knowledge sharing

we examine the literature on convergence and instances of convergence between AC and KA. Second, we present our bibliometric methodology for convergence analysis. Third, the results section illustrates the

primary convergence between absorptive capacity (AC) and knowledge appropriation (KA). We demonstrate how AC and KA have evolved over time, pinpointing the main thematic intersections, the profound impacts on key domains, and the intricate relationships and coevolution among central topics and areas of convergence. Finally, we discuss our findings, outline the main conclusions, and provide recommendations for future research.

2. Convergence literature

Convergence has been analyzed by the academic community to



Fig. 5. Part of speech analysis.

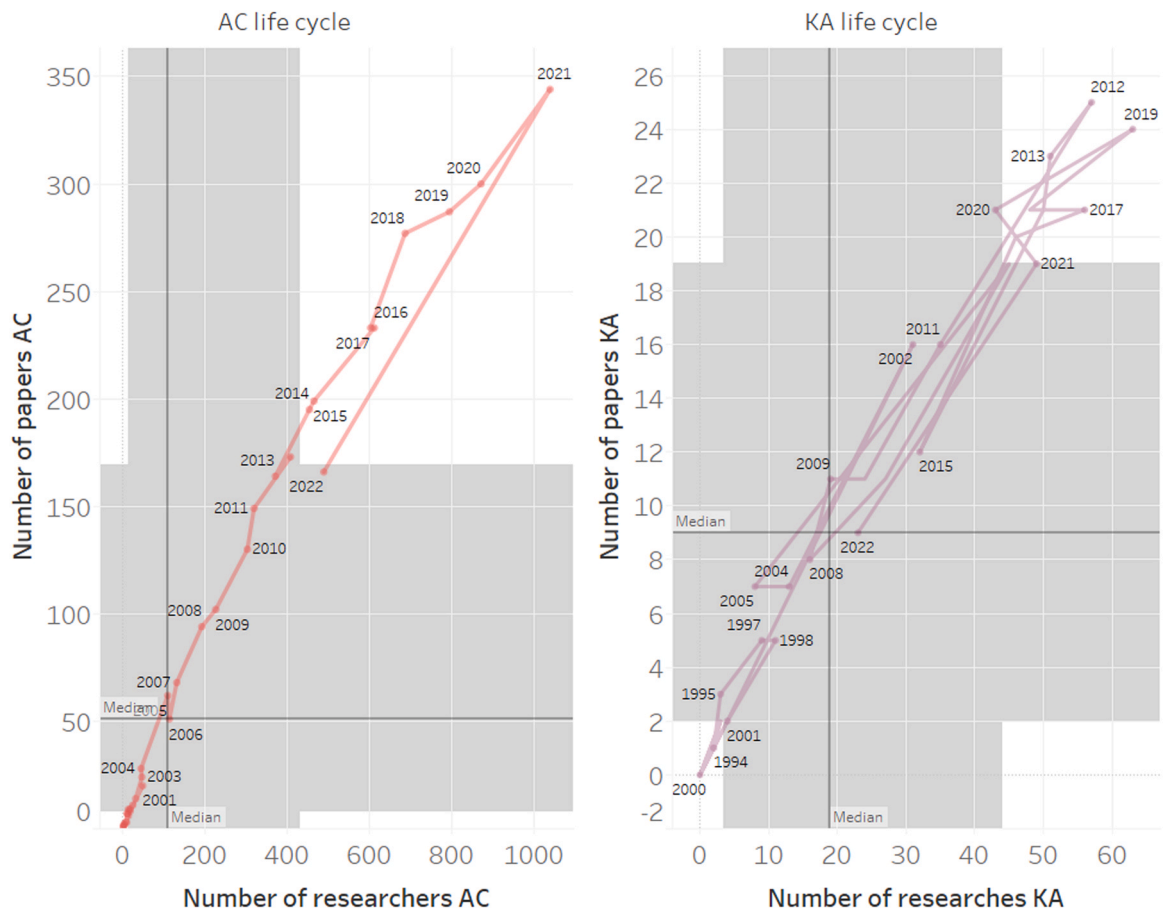


Fig. 6. Life-cycle convergence between AC and KA. Legend: In the provided diagrams, the left illustrates the AC life cycle and the right shows the KA life cycle. Both use a red line for the left trajectory and a purple line for the right. Quadrants are categorized into 'Emergent' (bottom left) and 'Growth' (top right) phases, with a division line marking the median number of papers and researchers.

Table 2
Changepoint years in KA and AC.

Changepoint	KA Year	AC Year
Media	2011	2013
Media Variance	2001	2004

recognize the affinity between fields and technologies and the occurrence of overlapping. Rosenberg (1963) introduced this concept to explore the Computer Numerical Control (CNC) industry. This notion has been mainly studied in technological fields (Jeong et al., 2015;

Shmulewitz et al., 2006; Sick et al., 2019). Another form of convergence is industrial convergence. It arises from the interconnections among industrial clusters (Chen et al., 2022) and is characterized by the application of technology from one domain to another (Curran et al., 2010), often termed as industry fusion (Bierly III and Chakrabarti, 2001).

In new product development, convergence unfolds through four stages: scientific, technological, application, and industry (Chen et al., 2022). According to Sick and Bröring (2022), convergence is an emerging topic.

Convergence has been studied in various areas, including



Fig. 7. Main topics in AC based on H-index, CAGR, and new topics. In the radial diagram presented, color-coded segments correlate to central metrics: orange for 'New Topics', green for 'CAGR', and blue for 'H-index'. The extent of each spike provides a quantitative measure for these metrics.

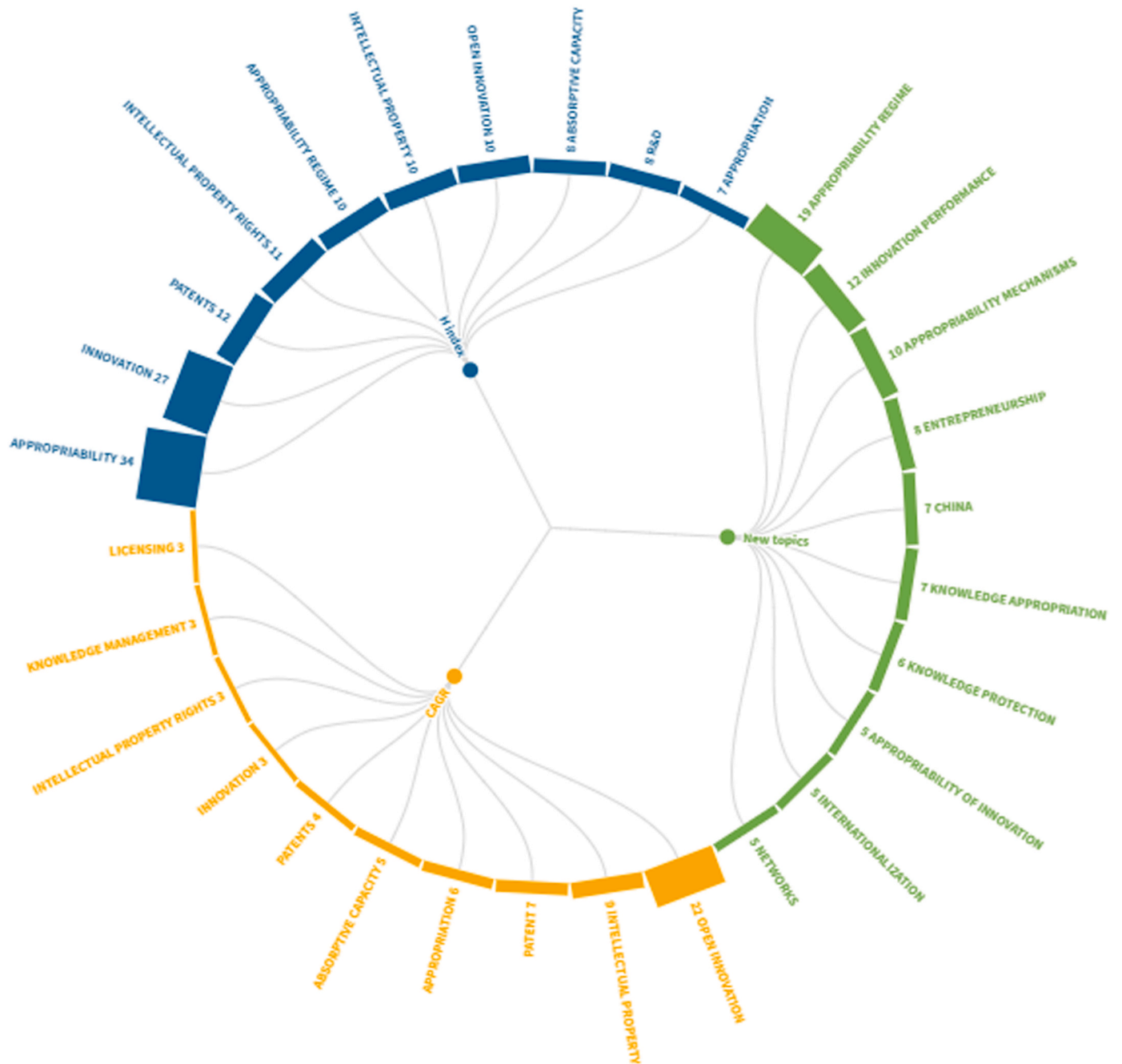


Fig. 8. Main topics in KA based on the H-index, CAGR, and new topics. In the radial diagram presented, color-coded segments correlate to central metrics: green for 'New Topics', yellow for 'CAGR', and blue for 'H-INDEX'. The extent of each spike provides a quantitative measure for these metrics.

Table 3
Some representative AC papers.

Reference	Topic	Description
Armstrong and Lengnick-Hall (2013)	Potential and Realized AC	Influence of social integration mechanisms in organizations.
(Popaitoon et al., 2021)	Potential and Realized AC	New product development in bipolar SMEs.
Sarsah et al. (2020)	Potential and Realized AC	Relationship between potential and realized AC, entrepreneurial orientation, and radical innovation performance.
(Seo, 2020)	Innovation performance	Mechanisms linking environmental dynamism with IP and the mediating role of AC and social innovation.
(Duan et al., 2020)	Open innovation	Effect of AC on organizational slack and IP.
(Lyu et al., 2022)		Relationship between social capital, IP, and AC's mediating role.
(Wu et al., 2021)		Relationship between Information Technologies and OI and the mediating role of potential and realized AC.
(Bianchi et al., 2016)	Technological innovation	Role of OI in acquiring technological knowledge.
(Mubarak and Petraite, 2020)		Relationship between OI, digital trust, and Industry 4.0.
(Xiongfeng et al., 2020)	Technological innovation	Impact of R&D investment on technological innovation and the role of talent mobility in increasing AC.
(Liu et al., 2020)		Influence of artificial intelligence on technological innovation, promoting knowledge creation, KS, learning, absorption, and investment in R&D.
(Du et al., 2015)		Relationship between technological diversification and technological innovation and the moderating effect of AC.
(Marcin, 2008)	KS	Effect of KS on FDI, relevance of AC in domestic firms, relationship between FDI and horizontal and vertical spillovers, and influence of AC on the size of spillovers.
(Al-Eisawi et al., 2020)	AC Dimensions (acquisition, assimilation, transformation, and exploitation)	Influence of AC dimensions on business intelligence systems.
(Miroshnychenko et al., 2021)	AC Dimensions	Nexus between AC dimensions, strategic flexibility, and business model innovation.

Additionally, we used Killick et al. (2012) changepoint analysis to identify single and multiple changepoints in the data. We compared the KA and AC changepoints using the same variables from the life-cycle analysis.

In contrast, we analyzed convergence based on topic similarities. We identify two types of convergence. The convergence areas are large topics or fields in which AC and KA converge. In contrast, we defined another category named building blocks, which identifies key topics in this convergence.

The main convergence areas and topics were identified in each field using the H-index (Hirsch, 2007; Moya et al., 2005), CAGR analysis (Elango, 2019), and new topics. In addition, we identified thematic clusters for each field using the Vosviewer tool, which allowed us to identify links and relationships between topics (Wang et al., 2022; Wang and Cheng, 2021), recognize main research areas, track cluster evolution, and assess their impact over time (van Eck & Waltman, 2010).

Additionally, to identify convergence, we employed a temporal convergence analysis methodology inspired by Malik (2019) splitting the analysis by different periods, allowing us to track the evolution of main topics annually. This thorough approach focused on discerning whether topics were present in both KA and AC literature (signifying convergence) or exclusive to one field (indicating divergence). For this analysis, topics were recognized using keywords with frequencies of 5 or more. The following table illustrates an example of this meticulous scrutiny. (Table 1).

To better understand how AC and KA influence the top convergence areas, we crafted a fresh approach. We looked at phrases that mentioned either AC or KA alongside these main areas. Using the part-of-speech analysis method from Toutanova and Manning (2002) and running in Knime software, we spotted key words: adjectives like "lower", verbs like "enhancing", and nouns like "effectiveness". This gave us a clearer picture of how AC and KA either positively or negatively affect these areas,

revealing another layer of convergence. For a visual, check out Fig. 5 which showcases our part-of-speech analysis.

Finally, we filtered the corpus to focus on the main convergence areas where AC and KA had a convergence ≥ 3 . Then, we blended AC and KA literature to investigate the influence of key elements in both fields. Next, we performed a co-occurrence analysis to investigate the relationship between the main building blocks and their impact on the convergence area (Cuellar et al., 2023). We also used social network analysis (SNA) to identify the importance of these building blocks in the network (Luan et al., 2021) and their relationship with impacts and the convergence area.

4. Convergence analysis between absorptive capacity and knowledge appropriation

4.1. Life-cycle convergence

We identified the AC and KA evolution that can be seen in Fig. 6. The emergent stage had a low number of publications and researchers. For AC, this stage began in 1989 and ended in 2006. For KA, it began in 1988 and ended in 2009. The growth phase had exponential development, as reported by most authors. It started in 2007 for AC and 2010 for KA and is still ongoing in both fields. The AC analysis had more publications than KA, with 290 articles in the emergent phase and 3122 in the growth stage. KA had 93 articles in the emergent phase and 275 articles in the growth stage.

In contrast to life-cycle analysis, changepoint analysis identified single and multiple changepoints in data using various common and unique changepoint techniques (Killick et al., 2012). We applied the same variables from the life cycle analysis—the annual number of authors and scientific papers—to compare changes in KA and AC. Our analysis showed that KA had a faster changepoint than AC regarding the

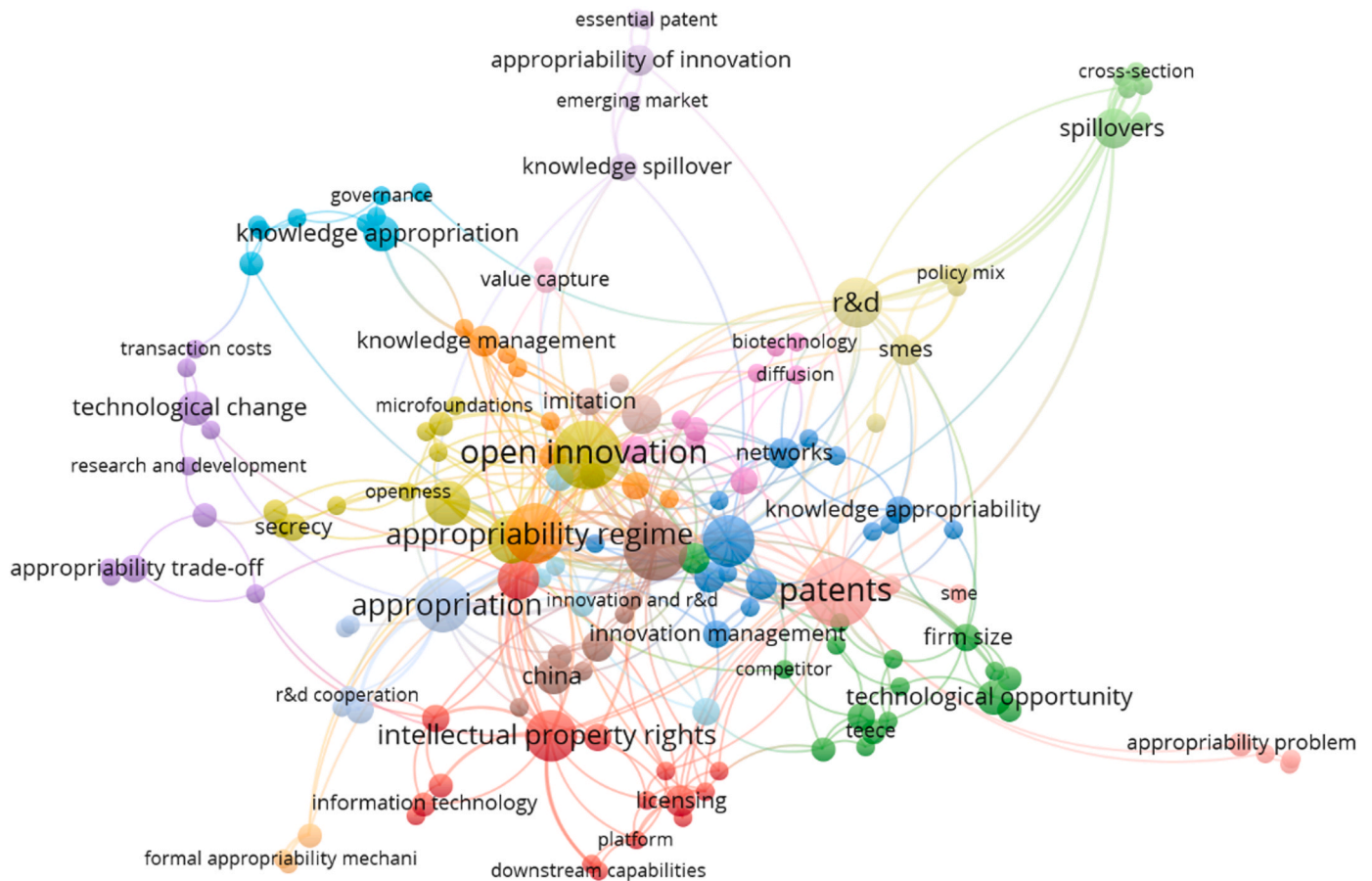


Fig. 11. KA keyword co-occurrence analysis. Legend: In the network visualization, colors distinguish thematic clusters; node size represents theme frequency, and edge thickness highlights link strength.

two indicators, as measured by the average and variance analysis. Table 2 illustrates the results.

Our analysis revealed several points of convergence between the two fields. For instance, AC and KA began at similar starting points and are currently in the growth stage. In addition, our changepoint analysis showed that the two fields experienced similar stage changes, with only a 2-year difference between AC and KA. These findings suggest a strong convergence of both domains based on the life cycle and changepoint analysis.

4.2. Convergence based on topic analysis

We compared the literature (AC and KA) to identify the convergence. First, we used the H-index to investigate the areas and building blocks relevant to AC and KA. The H-index measures the impact of terms based on the number of records and forward citations (Castaneda and Cuellar, 2021). CAGR was used to investigate the topics with the highest growth between the emergent and growth stages (Castaneda and Cuellar, 2021). Finally, new topics were recognized in the growth stage that had relevant productivity.

For AC, Fig. 7 shows that the most important topics in the H-index were AC, innovation, KM, organizational learning, and knowledge transfer. Based on a CAGR analysis, the most important topics were organizational learning, small and medium enterprises (SMEs), human

capital, technology transfer, and KM. According to our new topic analysis, open innovation, innovation performance, dynamic capabilities, entrepreneurial orientation, and firm performance were the most prominent trends in the field.

In KA, Fig. 8 shows that the most important terms based on the H-index were appropriability, innovation, patents, intellectual property rights, appropriability regime, open innovation, and AC. Furthermore, CAGR analysis revealed that the most important topics were open innovation, intellectual property, patents, appropriation, and AC. Regarding new topics, the most significant trends were appropriability regime, intellectual property, appropriability mechanism, and entrepreneurship. Our analysis indicates that AC has a greater impact on KA.

We identified the main trends in AC literature based on cluster analysis (Fig. 9). The cluster colors indicate different trends. The cluster in red shows that open innovation was the primary type of innovation model related to AC, the relationship between open innovation and SMEs, and the link between entrepreneurship and organizational learning. Blue shows AC and its link with technological innovation, ambidexterity, and knowledge creation. The blue-white color shows the other side of AC as a relevant element for IP and its relationship with dynamic capabilities.

Purple and brown demonstrate the impact of AC on knowledge spillovers (KS) and its relationship with foreign direct investment (FDI). The pink color indicates different dimensions of AC (acquisition,

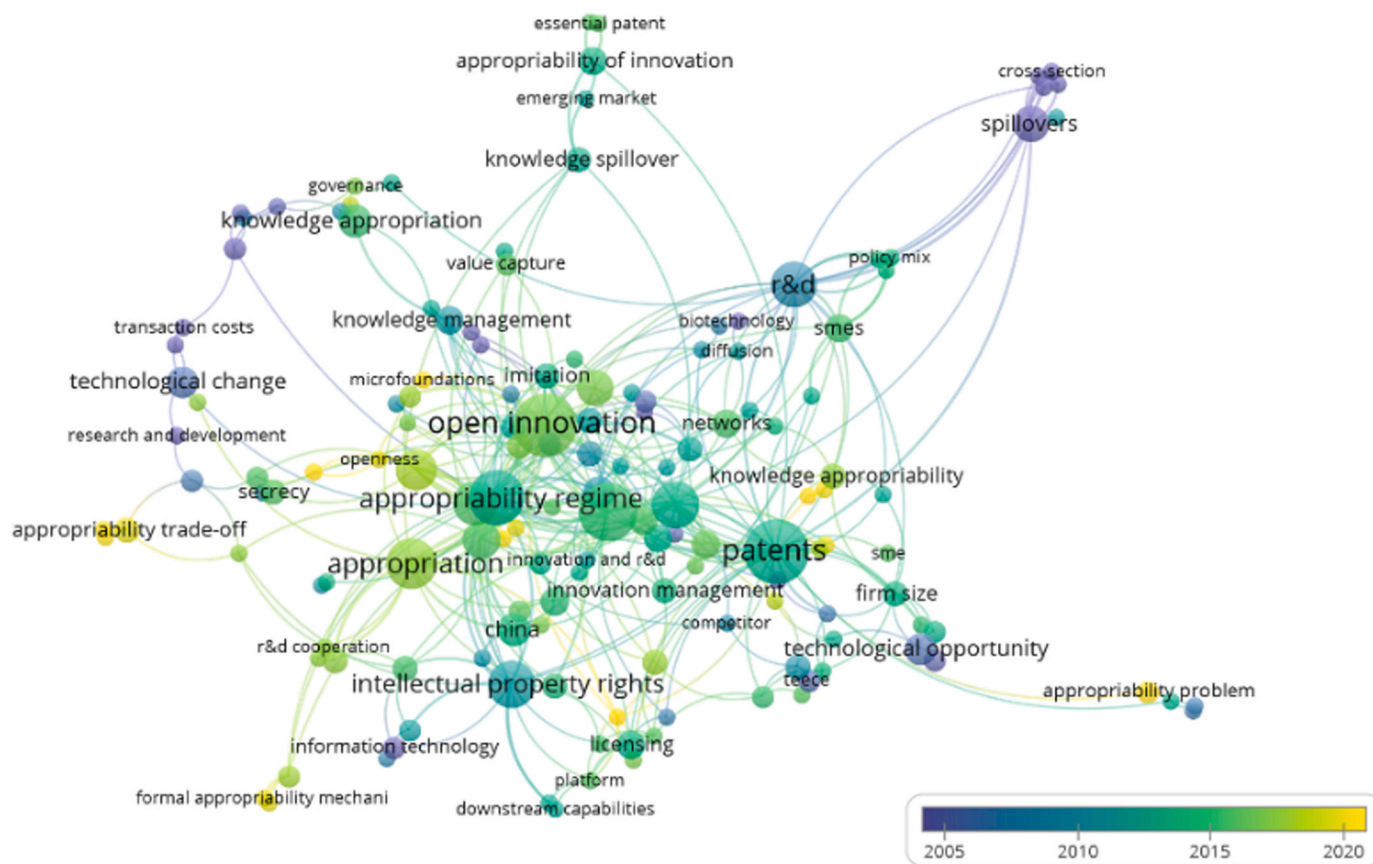


Fig. 12. KA keyword evolution co-occurrence analysis. Legend: blue highlights older themes, yellow the recent; node size denotes frequency, and edge thickness shows connection strength.

assimilation, transformation, and exploitation). In addition, the light green matched the model created by Zahra and George (2002) on synthesizing the acquisition and assimilation stages in potential AC and transformation and exploitation in realized AC.

Furthermore, we identified topics that have the greatest impact recently (Fig. 10). A notable new concept is green AC in relation to eco-innovation. Another important new topic is the relationship between AC and emerging technologies, such as Industry 4.0, digital transformation, and ambidexterity. Some topics, such as technology diffusion, organizational learning, organizational change, and value creation, have become less relevant.

Moreover, we identified the most important academic papers on the most important trends by examining the frequency of each topic in each paper’s key bibliographic field (title, abstract, and keywords). The next table shows some representative scientific papers. Table 3.

With respect to KA, the number of key clusters (Fig. 11) was lower than AC cluster. The brown cluster focused on intellectual property and the main mechanisms of appropriation. Yellow analyzed appropriability mechanisms and their relationship with open innovation. Orange studied the appropriability regime and its link with KM. In addition, this cluster analyzed KA’s link with the type of knowledge (tacit or explicit) and the first-mover advantage as a type of appropriation mechanism. Green and pink represent patents (another key KA mechanism), technological appropriation, and technological innovation, respectively. Violet studied KS, technological change, and appropriability tradeoffs

and red analyzed technology transfer and some essential elements of this process as licensing and Trade-Related Aspects of Intellectual Property Rights (TRIPS).

Fig. 12 shows the cluster time evolution in KA. We identified new trends in appropriability, tradeoffs, technological congruence, process innovation, open innovation, entrepreneurship, R&D cooperation, and technological complexity. Moreover, other topics, such as KS and technological changes, have lost their relevance.

The most relevant articles based on the main trends in KA were also identified using the frequency of the topic in key topic fields (title abstract and keywords). (Table 4).

Cluster analysis showed a strong convergence in innovation, especially in innovation performance and open innovation. Other relevant convergence areas were KS and entrepreneurship. The AC and KA fields have been associated positively with these topics as having a mediating role or positive effects on each field over these topics. The main divergences were found in specific areas of each field, such as AC dimensions and KA mechanisms.

4.3. Convergence between KA and AC over time

We measured convergence using the approach shown in Table 1. We performed an S-curve analysis based on Ernst (1997) to understand KA and AC convergence (Fig. 13). We split the growth stage into two stages to visualize convergence. S1 was defined as an emergent stage with low

Table 4
Some representative KA papers.

Reference	Topic	Description
(Cohen et al., 2002) (Harhoff, 1996) (Alnuaimi and George, 2015) (Martin, 2002) (Bahemia et al., 2017)	KS	Positive effect of Japan's policies in generating KS and KA compared with the U.S. Positive effects of KS when KA levels are weak. Studied knowledge retrieval type of KA associated with recovery KS. Effects of input KS, imperfect appropriability, and their link with innovation.
(Holgersson et al., 2018) (Hannigan et al., 2018)	Open innovation	Identified innovation type, appropriability regime, and product complexity in new product development. Impact of complementary and substitute KA in systemic open innovation. Studied knowledge flows, product innovation rumors in the software industry, role of KA in open innovation processes.
(Chung and Lee, 2020)	Intellectual property	Positive effect of knowledge exchange activities and application of KA informal mechanisms over intellectual property.
(Hurmelinna-Laukkanen, 2014; Hurmelinna-Laukkanen and Puumalainen, 2013) (Cheng et al., 2014)		Effects of KA and AC over rival intellectual property Role of dynamic capabilities and KA in intellectual property in supply chains.

convergence. S1 has four keywords that converged. S2 was a consolidation stage with large variability and convergence like that of S1. At this stage, 33 keywords converged. S3 was defined as the first growth stage when the convergence started to exhibit exponential growth. S3 had a total number of 63 converging keywords. Finally, S4 was the last growth stage, with exponential growth and 77 keywords converging.

In contrast, we identified the main areas of convergence. AC and KA converged with a relevant frequency in all stages (Fig. 14), confirming that both topics were strongly linked, as Cuéllar et al. (2022) showed in their paper. Another relevant topic was *patents*, one of the main KA mechanisms that increased the convergence in recent periods. However, the main topic with more convergence between the fields was *innovation*, represented by keywords such as open innovation, innovation performance, product innovation, innovation management, and new product development. *Entrepreneurship* started to be relevant in KA and AC convergence in the last period, as well as internationalization. *R&D* was a key topic in S2 and S3, but it was not recognized as key in S4.

Our semantic analysis shows that open innovation, innovation performance, entrepreneurship, and KS are the main converging areas of AC and KA. We identified the effect generated by KA on these topics and AC on these topics to compare both fields. We followed the process illustrated in Fig. 3. Regarding innovation, we found that the main effect of KA on this topic was a *moderator* element, generating a positive influence. In addition, KA was found to be an element that *enhances, increases, and improves* innovation performance and open innovation. Only two studies have examined the negative effect of KA on innovation. We identified an inverse relationship between KA and KS; the main outcome was that KA *reduces* KS. However, other studies have found a positive effect of KA on KS, *increasing* and *mediating* KS. Finally, some authors have recognized the *positive* effect of KA on entrepreneurship. (Fig. 15).

Regarding AC effects on open innovation and innovation performance, our analysis shows a *positive* effect, mediating innovation performance and open innovation, *moderating, enhancing, improving, increasing, promoting, achieving, benefiting, and facilitating* innovation performance and open innovation. However, some authors identified a *negative* effect of AC over innovation performance and open innovation, although the number of academic papers that showed a negative effect was considerably lower than that showing a positive effect. Regarding AC and KS, some authors have identified the positive impact of AC on KS: *increasing, improving, contributing, moderating, enhancing, promoting, mediating, facilitating, and stimulating* KS. In contrast, other authors have identified a negative effect of AC over KS, *reducing* and *decreasing* KS. AC

also plays a relevant role in *mediating, moderating, enhancing, promoting, improving, benefiting, and increasing* entrepreneurship. The convergence of the positive effect of AC and KA on innovation, entrepreneurship, and KS can be seen in some terms as a positive effect or the moderating effect, influence, promotion, enhancement, and contribution. (Fig. 16).

We also explored other elements influencing the generation of innovation, entrepreneurship, and KS. After examining the literature on both topics, we identified the key elements - or building blocks - crucial for their convergence. Fig. 17 illustrates these building blocks and their significance in the network, as determined by SNA indicators. Our analysis indicates that R&D, patents, and networks are the pivotal building blocks in the convergence of AC and KA. These topics have robust connections to other essential network elements. KM is closely connected to networks, while intellectual capital is strongly associated with both R&D and networks. Additionally, R&D maintains a potent relationship with patents.

Fig. 18 presents the cluster analysis, which identifies the most closely related topics based on cluster colors. The primary clusters identified encompass patents, foreign direct investment, and R&D. Another cluster groups together networks, internationalization, and knowledge protection. A different cluster combines intellectual capital, ambidexterity, sustainability, digitalization, and stakeholders. Additional clusters include topics such as KM, dynamic capabilities, knowledge transfer, and financial capabilities. Yet another group features openness, information technology, and new product development. The final cluster comprises SMEs, firms, and knowledge conversion.

Fig. 19 shows the analysis done with SNA indicators. The betweenness centrality reveals that certain building blocks serve as bridges between different clusters, while degree centrality points out topics that are more interconnected with others. From these SNA indicators, the standout topics include R&D, firm size, SMEs, patents, KM, sustainability, internationalization, FDI, and intellectual capital. As per the degree centrality from the SNA indicators, the predominant topics are networks, IT, and knowledge transfer. Notably, digitalization emerges as a significant topic in betweenness centrality but not in degree centrality. The subsequent pie chart illustrates the significance of each topic for AC (highlighted in yellow) and KA (in red), gauged by their publication frequency in each domain. Topics prominently featured in both fields encompass R&D, patents, SMEs, firm size, KM, networks, knowledge protection, knowledge externalities, preemptive patenting, stakeholders, and knowledge conversion.

The following figure illustrates the relationship between each

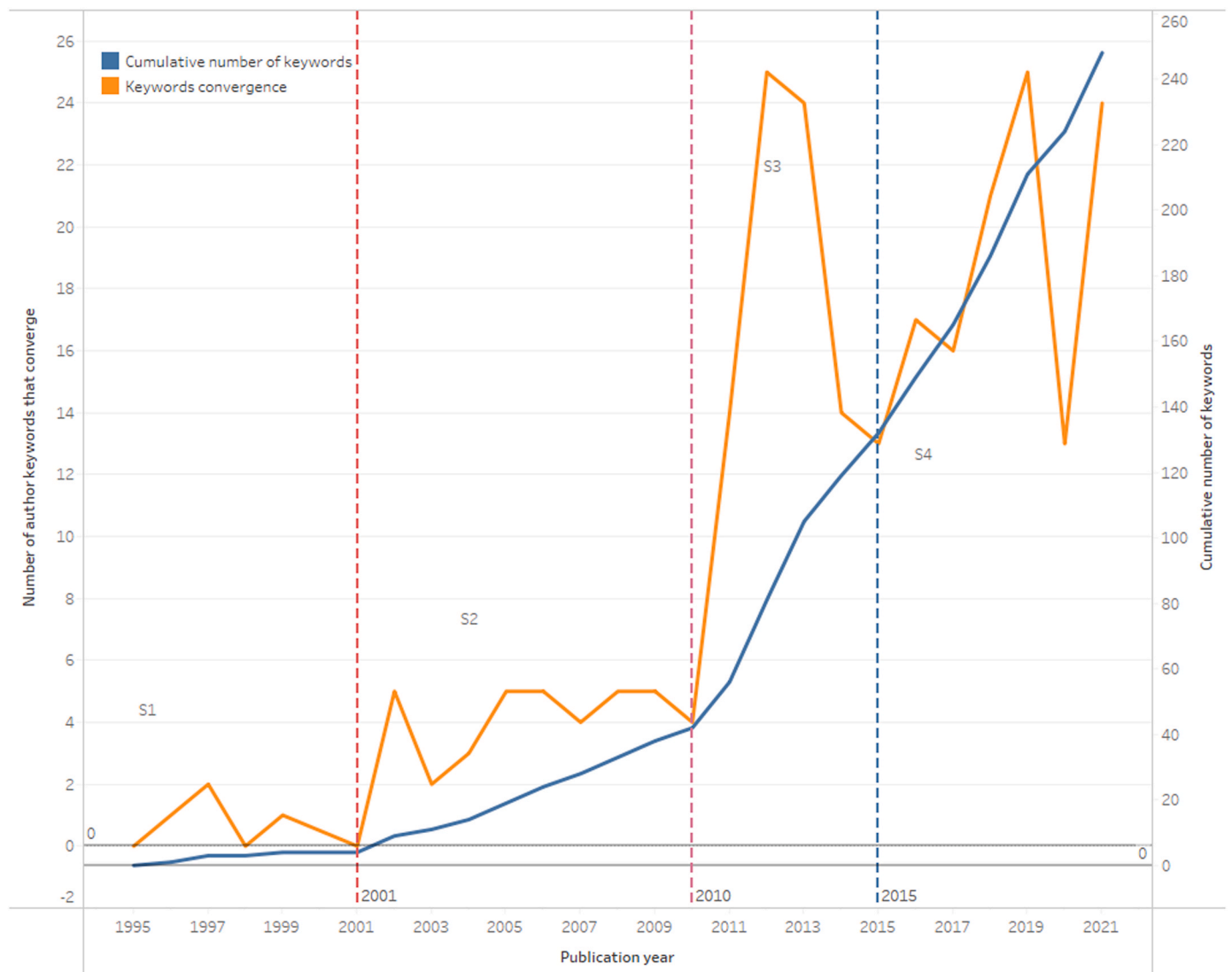


Fig. 13. AC and KA convergence evolution in time. Legend: The chart shows four phases: S1 (up to 2001), S2 (2001–2010), S3 (2010–2015), and S4 (after 2015). The blue line marks cumulative keyword convergence, while the orange line represents annual convergence frequency.

building block and its impact on primary convergence areas. The R&D building block is particularly notable, while Intellectual Capital and KM closely follow in significance. Moreover, Networks and patents exhibit notable positive impacts. Upon closer examination, the prevailing positive influence is termed "Enhance." This influence plays a crucial role in strengthening the connection between the building blocks and central convergence areas such as innovation performance, KS, and open innovation. This dynamic underscores the importance of these building blocks in shaping the direction of the targeted convergence areas.

Conversely, some building blocks have adverse effects on convergence areas. The R&D block is especially prominent in this regard. Patents and foreign direct investment also display some negative tendencies. The most significant negative impacts are evident in KS, innovation performance and open innovation, highlighting the potential challenges posed by these building blocks in these areas. (Fig. 20).

5. Discussion

AC and KA are pivotal in transferring technology and innovations to society, with both fields historically interconnected, as highlighted in primary AC models, and specialized literature (Cuéllar et al., 2022; Hurmelinna-Laukkanen, 2012b; Sun and Zhai, 2018). While some researchers, like Cuéllar et al. (2022), have started addressing this, we identified a gap in uncovering hidden connections through our literature review.

Convergence analysis has been used to identify hidden relationships between areas (Bornkessel et al., 2015; Curran et al., 2010; Curran and Leker, 2011). Few studies have explored convergence in the management field (Bosch and Grobbelaar, 2021; Ibrahim et al., 2021; Moutinho and Silva, 2021; Popkova and Sergi, 2020), to our knowledge, no research has specifically addressed the convergence of AC and KA.

Our research question for this study was: What are the hidden links between AC and KA, and how do they converge in the context of

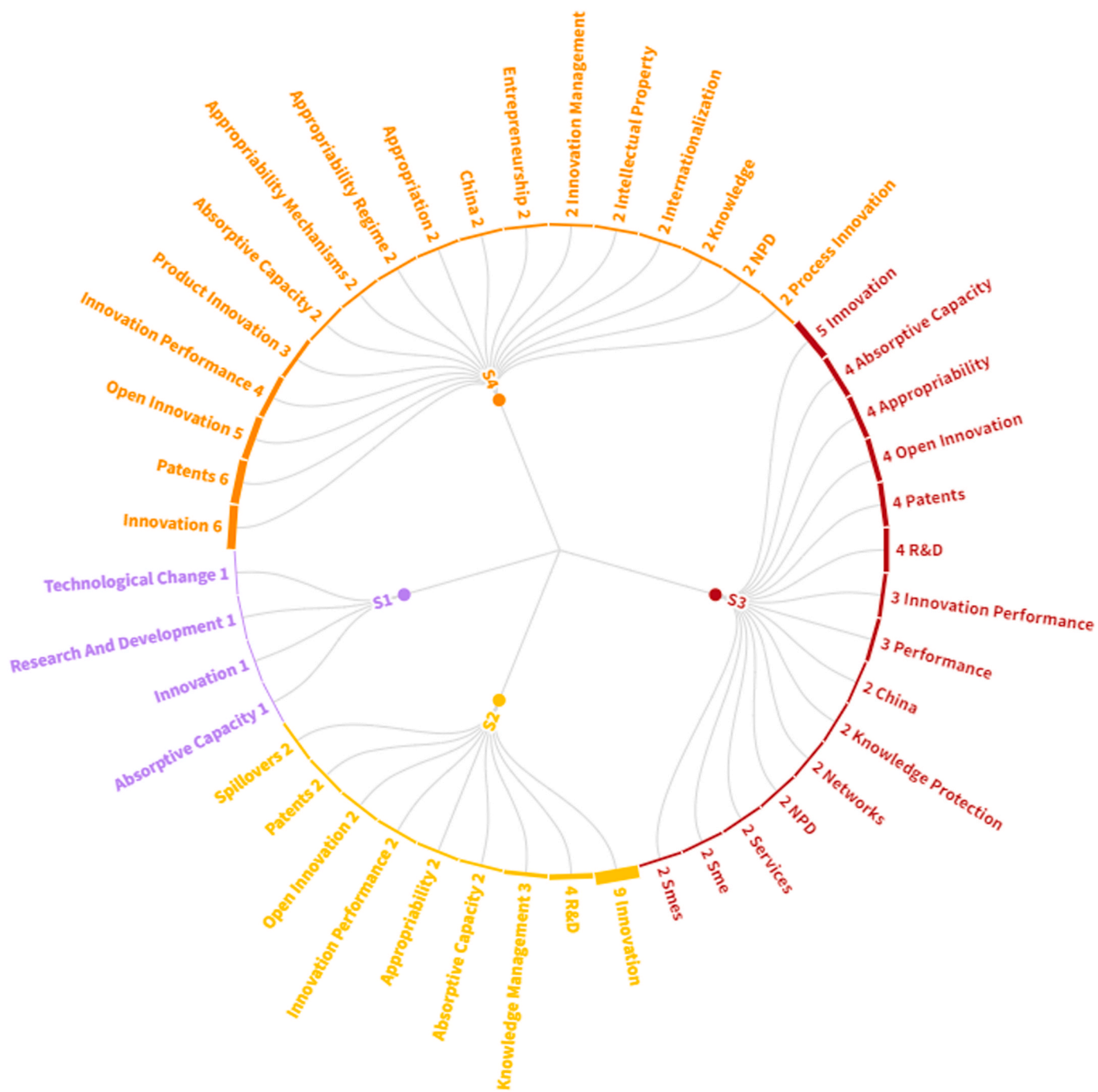


Fig. 14. Convergence topics between AC and KA in time. Legend: Four phases of keyword convergence: S1 (purple) up to 2001, S2 (yellow) 2001–2010, S3 (red) 2010–2015, S4 (orange) post-2015. Numbers indicate convergence frequency.

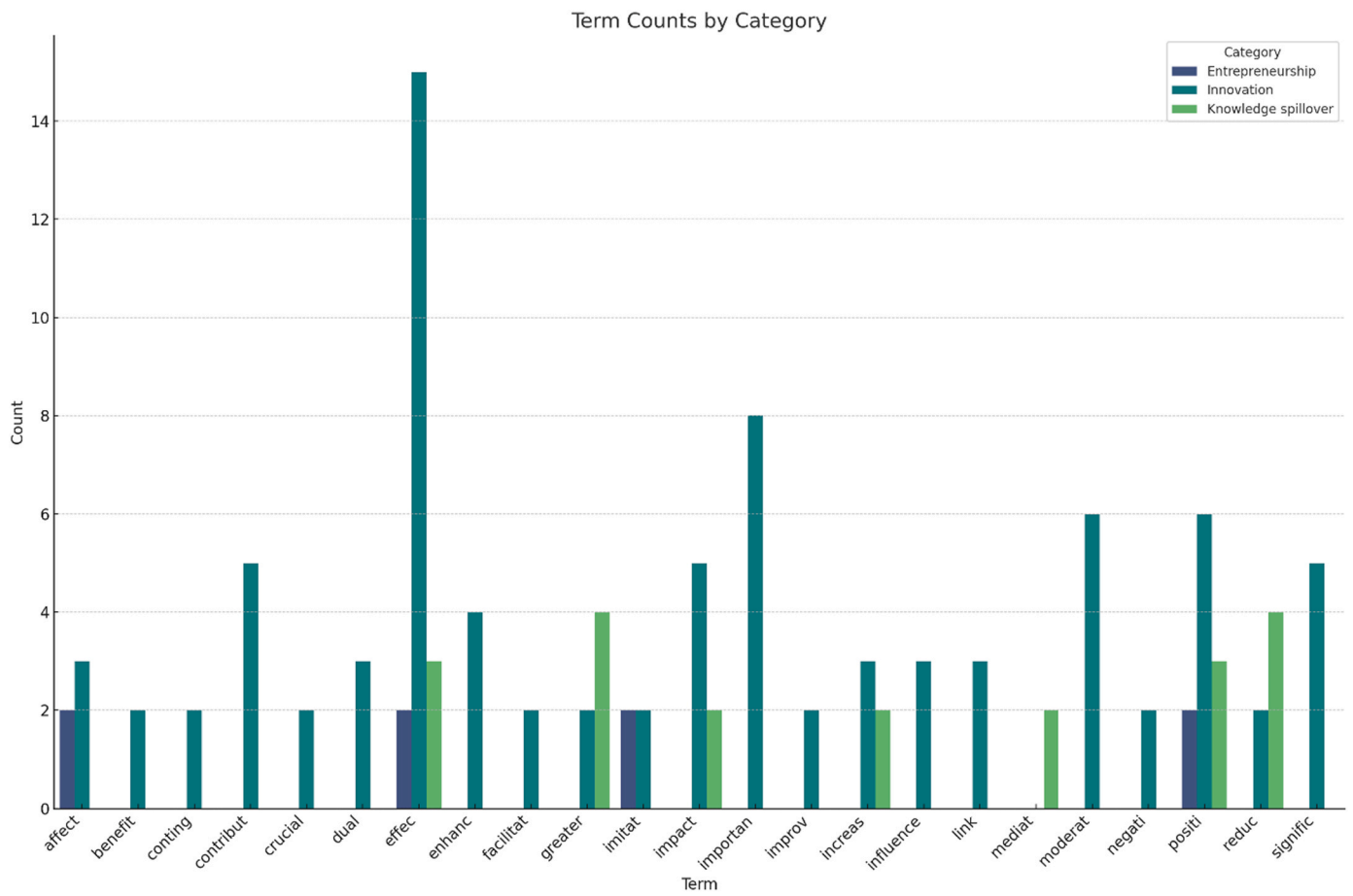


Fig. 15. KA effects over innovation, knowledge spillover, and entrepreneurship.

management studies?. To answer this question this study analyzed the convergence of KA and AC based on different elements, such as evolution over time and topic convergence. Convergence was analyzed based on the topic of convergence. The convergence of AC and KA was analyzed based on the impact of each on innovation, entrepreneurship, and KS (areas identified as key in our analysis). Finally, we identified the building blocks (other key elements in the growth medium) that were key to convergence.

Our research revealed a pronounced convergence between AC and KA, evidenced by parallel timelines and mutual influences within specific fields. Life-cycle analysis indicated that AC evolved at a faster pace than KA. However, both AC and KA exhibited notable similarities in their evolution, notably their emergence in management disciplines during the latter part of the 1980s Cuéllar et al. (2022) pinpointed that foundational papers of both domains emerged in the latter part of the 1980s. The transition from the emergent phase to the growth stage marked another convergence point for both fields. AC entered the growth phase in 2007, closely followed by KA in 2010. A changepoint analysis revealed a mere two-year gap between their respective transition points.

Bornkessel et al. (2015) noted the rarity of using life cycle for convergence analysis in academic topics. Our study offers a unique

contribution in this area.

In our study, we explored thematic convergence. While past research measured convergence using clusters (Ciomaga, 2015), semantic analysis, machine learning, and bibliometrics (Kim and Sohn, 2020), we introduced a novel method. This approach combined the H-index, CAGR, and new topics approach with a unique keyword comparison between AC and KA to identify annual convergence. Additionally, we assessed the impact (both positive and negative) of KA and AC on primary convergence topics and key elements. This method provided a comprehensive and detailed view of convergence topics.

Using the H-index, we pinpointed major topics with vast publications and citations. CAGR analysis highlighted rapidly emerging subjects, while new topic analysis unveiled previously overlooked themes. Open innovation and innovation performance stood out as primary convergence fields. Thematic cluster analysis underscored the significance of open innovation and KS. Time-based keyword assessment showed a rising convergence between AC and KA, emphasizing areas like open innovation, innovation performance, innovation forms, patents, foreign direct investment, SMES and entrepreneurship. Notably, the significance of KM in convergence appears to be diminishing.

We identified topics that covered many subtopics and were relevant to convergence. These were termed "convergence areas." The key areas

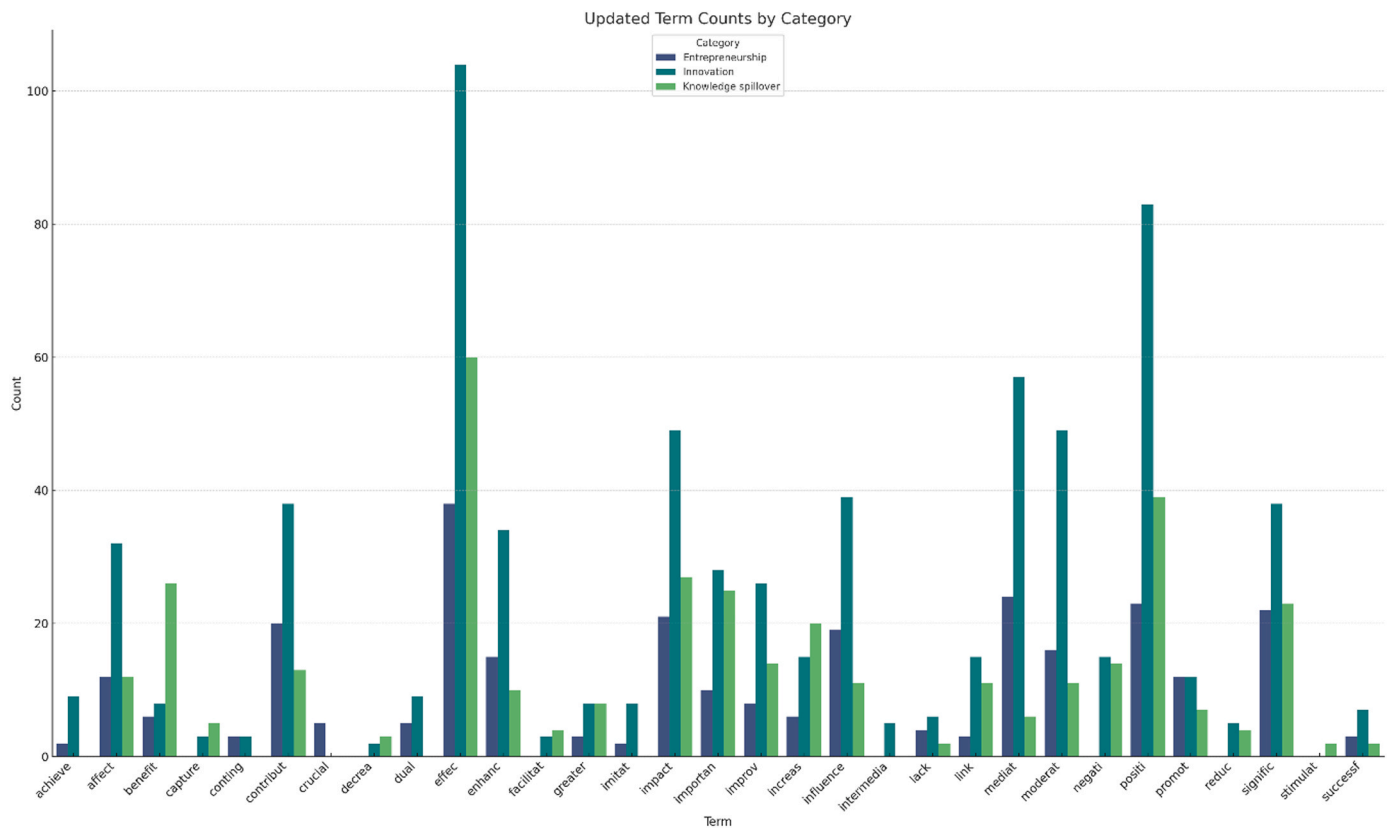


Fig. 16. AC effects over innovation, knowledge spillover, and entrepreneurship.

were *innovation*, *entrepreneurship*, and *KS*. These are rather present in the literature and are the main convergence points of AC and KA.

We identified the effects of KA and AC on these topics and terms related to their impact on these key topics. Our results show that each field (AC or KA) is mainly associated with generating a positive effect over key areas. The major positive impacts were the "positive effect," the "moderator effect," influence, promotion, enhancement, and contribution.

Concerning KA, a dichotomy in its effect on KS is evident. Hurmelinna-Laukkanen and Yang (2022) differentiate KA into distinct concepts. They describe appropriability conditions as factors influencing the use of appropriability instruments and processes. Strong appropriability conditions enable benefits from external knowledge at a macro level. Conversely, they define "realized KA" as the process where innovators achieve both private and societal returns using appropriability instruments. When realized KA is robust, it negatively impacts spillovers by impeding knowledge exchange.

Regarding our definition of the main areas of convergence, our outcomes are validated by some specialized literature, such as Sun and Zhai (2018), who identified open innovation and entrepreneurial venture as key topics in KA literature, and Hurmelinna-Laukkanen (2012), who recognized AC and KA as key drivers of innovation performance. The importance of AC and KA over knowledge management have been validated for other authors as Cuéllar et al. (2022).

In our analysis, we blended AC and KA literature to explore factors

influencing innovation, entrepreneurship, and KS. Focusing on studies directly linked to these topics, we utilized Social Network Analysis (SNA) to identify key building blocks for these outcomes. Degree centrality revealed the interconnectedness of these elements, while betweenness centrality highlighted those bridging major thematic clusters (Luan et al., 2021). Notably, R&D, patents, SMEs, firm size, and knowledge management were central in both metrics, emphasizing their role in the convergence of AC and KA.

The study outlines a complex coevolution of AC and KA, highlighting an evolving interdependence through time. Pre-2001, the emphasis was on R&D and integrating new processes. Post-2001, the focus shifted to evaluating innovation outputs and incorporating OI, with patents becoming essential for knowledge transfer. From 2010–2015, attention turned to the impact of key players like China and SMEs on innovation pathways, with an increased focus on NPD and patenting. After 2015, the conversation broadened to internationalization and entrepreneurship, with a variety of mechanisms for knowledge appropriation, where patents remained significant. AC and KA's coevolution is defined by fundamental components such as R&D and patents, which underscore their interlinked growth.

KM is central to the diffusion and application of knowledge, with intellectual capital closely tied to R&D and networks, crucial for knowledge generation and usage. Thematic clusters reveal complex interactions across networks, internationalization, knowledge protection, digital transformation, and stakeholder engagement. Additional clusters

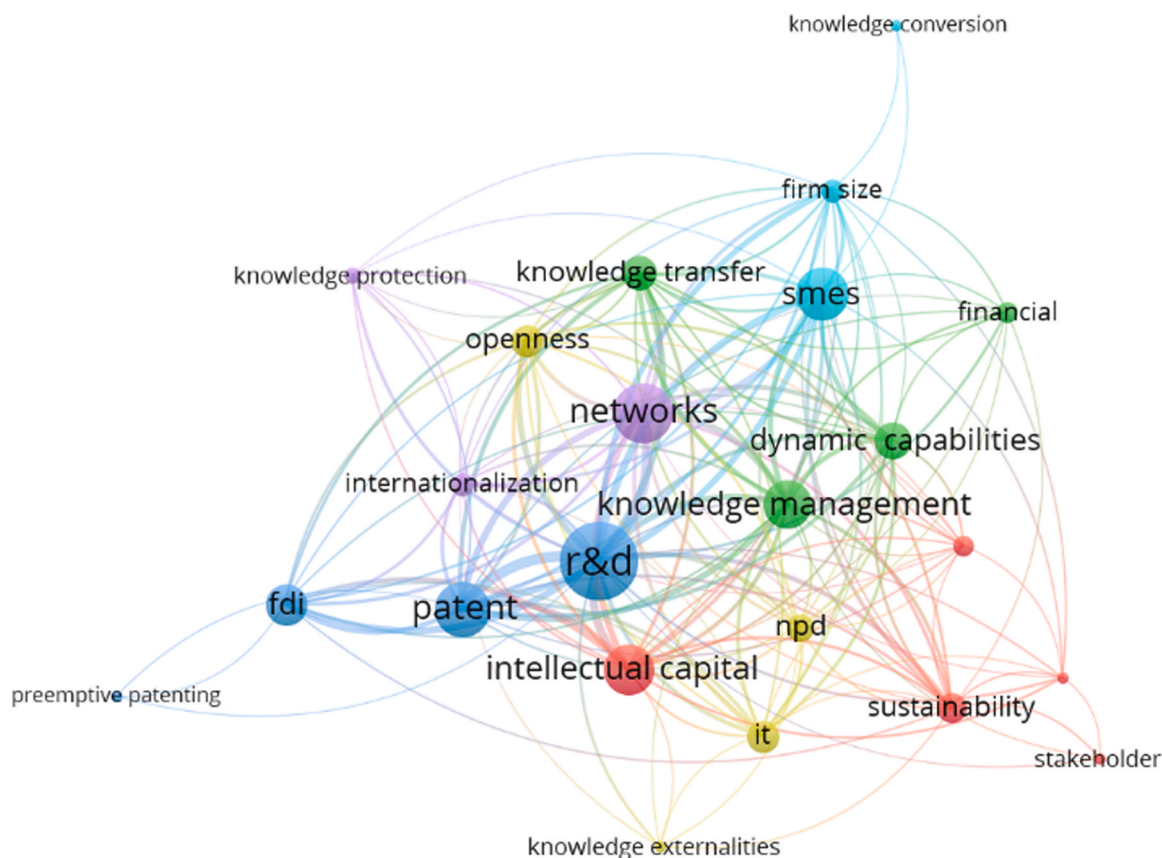


Fig. 18. Clusterization of the main building blocks in the convergence between AC and KA. Legend: Color-coded clusters represent related building blocks. Thicker lines indicate stronger relationships between terms.

involving KM, dynamic capabilities, knowledge transfer, financial expertise, and IT are key to AC and KA. These clusters signify a deeper integration, suggesting robust interrelations that enhance coevolution understanding. The strategic synergy between R&D and patenting forms a nexus for advancing knowledge protection and commercialization.

Patents hold a pivotal role in the convergence of AC and KA. Often, they serve as a primary KA appropriation mechanism, as highlighted by studies from [Bahl et al. \(2021\)](#) and [Barros \(2021\)](#). Additionally, some researchers utilize patents as an indicator to measure AC ([Malik et al., 2021](#)), further emphasizing their intertwined nature. This interconnectedness is intrinsic, suggesting that patents are integral to both AC and KA's core. [Sun and Zhai \(2018\)](#) identified patents as key elements in specialized studies on KA. Furthermore, several authors, including [Alnuaimi and George \(2015\)](#) and [Dushnitsky and Lenox \(2005\)](#), have underscored the significance of patents in fostering and impacting innovation, particularly when combined with AC and KA. Thus, the prevailing literature underscores our assertion about the centrality of patents in the AC and KA convergence.

R&D has been highlighted by researchers as pivotal in driving innovation in conjunction with KA and AC. ([Amoroso and Audretsch, 2022](#); [Park and Lee, 2022](#); [Roud and Vlasova, 2020](#)). Several authors have utilized R&D as a metric for AC, including [Behera \(2015\)](#) and [Hervas-Oliver et al. \(2011\)](#). The significance of R&D, along with KA, is

evident in innovation ([Kim, 2022](#); [Martinez-Noya & Garcia-Canal, 2018](#)), entrepreneurship ([Da Silva & Teixeira, 2012](#); [de las Heras Rosas & Ballesteros, 2021](#); [Spulber, 2012](#)), and KS ([de Almeida et al., 2021](#); [Egbetokun & Savin, 2012](#); [Roy & Paul, 2022](#)). [Sun and Zhai \(2018\)](#) further emphasize R&D's centrality in KA literature. These studies confirm our findings that R&D is a pivotal convergence point between AC and KA.

Several authors emphasize the role of KM alongside AC and KA in promoting innovation and KS. Specifically for entrepreneurship ([Gimenez-Fernandez et al., 2022](#)) and KS ([Alnuaimi and George, 2015](#)) significance is underscored in conjunction with KA. Codified knowledge stands out in KA literature ([Sun and Zhai, 2018](#)). Firm size, especially SMEs, is central in both AC and KA studies. For example, [Oliveira et al. \(2020\)](#) explored KA and AC within SMEs. However, while organizational learning is prominent in AC, it's less so in KA. Similarly, dynamic capabilities and AC dimensions are key in AC but not in KA. These differences offer avenues for deeper investigation.

6. Conclusions and limitations

Our analysis reveals a pronounced convergence between Absorptive Capacity (AC) and Knowledge Appropriation (KA) in shaping innovation, entrepreneurship, and Knowledge Spillovers (KS). Employing a

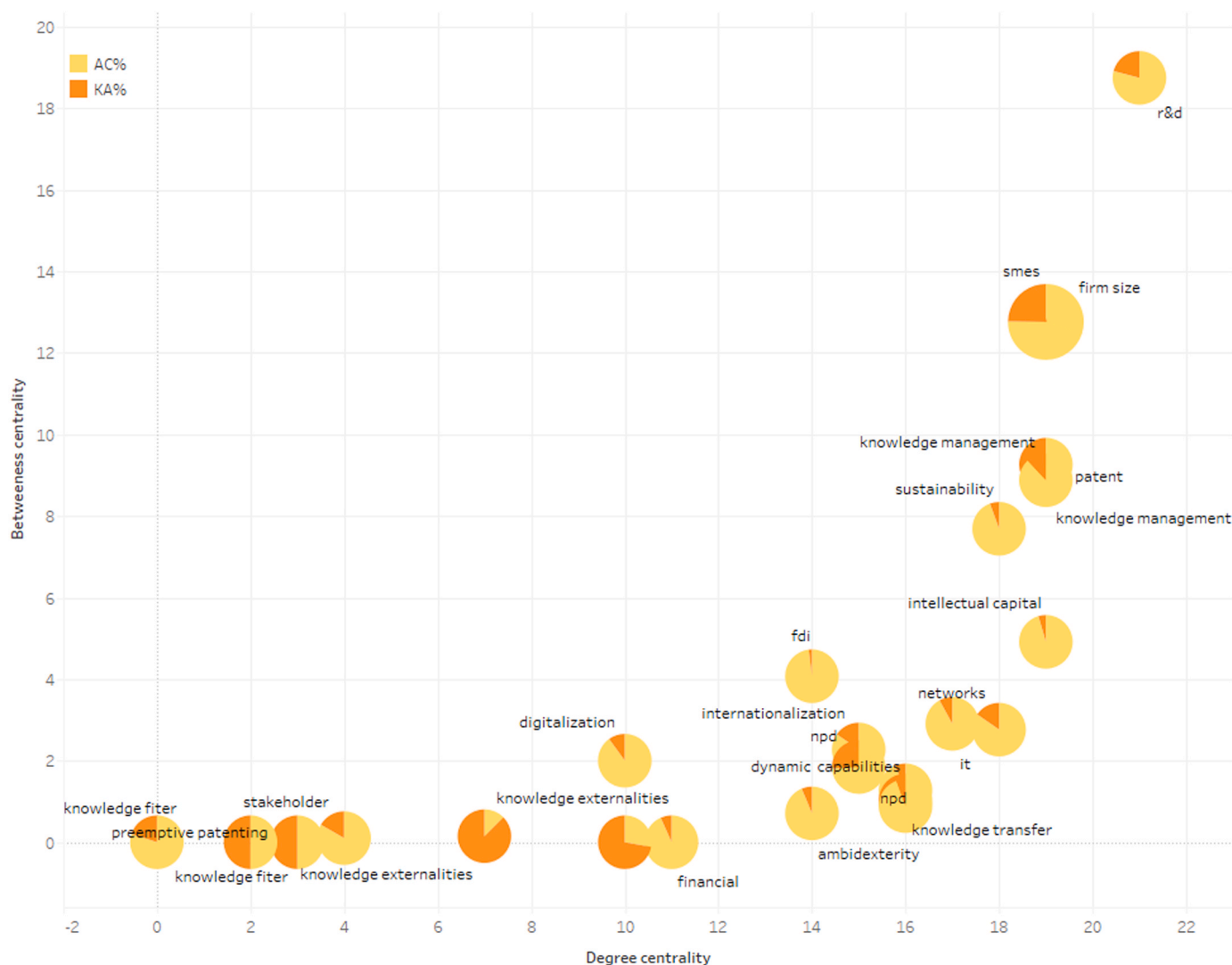


Fig. 19. Relevance for KA and AC of the main building blocks and importance by degree centrality and betweenness centrality. Legend: The X-axis displays topics with extensive interconnections. The Y-axis emphasizes bridge topics between clusters. The area of the pie chart indicates the importance of the topic in each field (KA or AC).

life-cycle approach and a unique thematic convergence methodology, we identified mutual influences and convergent areas like Open Innovation (OI) innovation performance (IP). Key building blocks driving this convergence include R&D, patents, SMEs, and Knowledge Management (KM). While the intertwined nature of AC and KA was evident, notable divergence points also emerged, like the significance of organizational learning in AC but not in KA. This study bridges a critical gap, highlighting the symbiotic relationship between AC and KA and suggesting avenues for future interdisciplinary research.

Our outcomes open many possibilities for studying KA and AC in combination with different convergence points (e.g., R&D, KM, and patents) for relevant topics such as innovation, entrepreneurship, and KS. Our study tracked possible roadmaps or indicators for studying these topics.

Our methodology can be replicated across various fields of literature, particularly in management where convergence analysis is limited, as well as in patent and market research literature where such analysis

holds significant importance. Full-text analysis could enhance the depth and breadth of this methodology and the understanding of convergence. Furthermore, empirical research on KA and AC in emerging economies, and the influence of key sectors such as KS on innovation, represent additional domains where our findings could be utilized. Importantly, the building blocks identified through our research offer a foundation for developing new methodologies and indicators that can more accurately measure and assess the intricacies of AC and KA.

Our study had some limitations. The research used bibliographic information specifically for topic analysis with titles, abstracts, and keywords. A full-text analysis is more precise for convergence analysis. Additionally, we used the Scopus and Web of Sciences Databases. Other resources such as ScienceDirect, Google Scholar, and Lens would improve the scope of this type of study.

Our analysis confirmed the hypothesis that AC and KA have strong direct links, as Cuéllar et al. (2022) showed, but based on identifying hidden links between AC and KA. The convergence is strong between

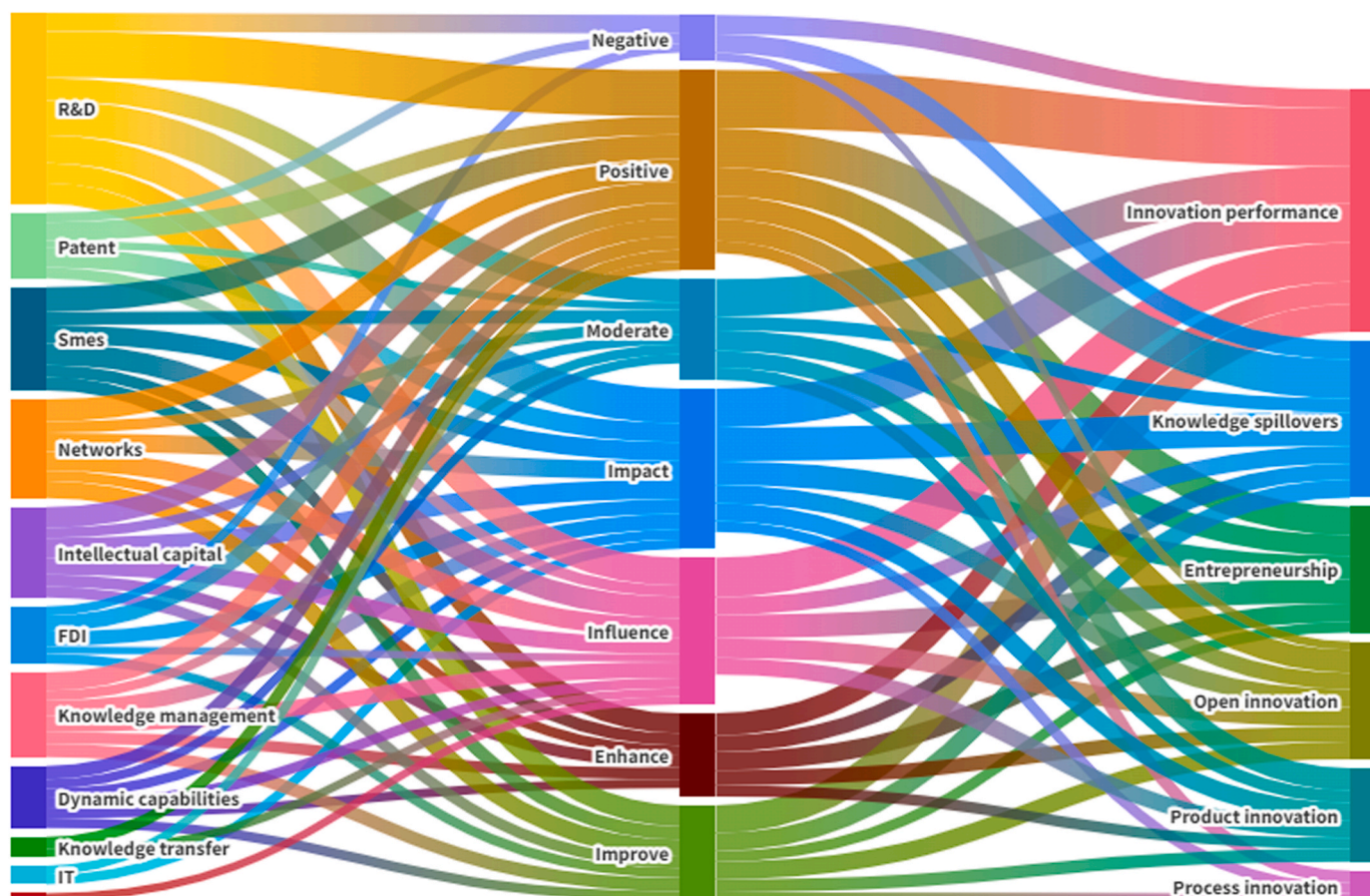


Fig. 20. Relationships between main building blocks, impacts, and key areas in the convergence between AC and KA. Legend: Left shows building blocks, center their effects, and right the impacted areas. Thicker edges highlight stronger relationships.

these fields, and this should motivate further studies that combine both, for example, to study emergent innovation topics, such as frugal innovation, and other trend topics, such as Industry 4.0, and the influence of AC and KA, or to study the relevance of AC and KA in emerging economies characterized by weak innovation ecosystems.

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Dataset: <https://data.mendeley.com/datasets/3djyh62cz8>.

CRedit authorship contribution statement

Sergio Cuellar: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – original draft, Visualization, Project administration. **Felix de Moya-Anegón:** Conceptualization, Writing – review & editing, Supervision, Project administration. **Maria Teresa Fernandez Bajon:** Supervision, Project administration.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Chat GPT-4 to improve readability and language understanding. After utilizing this AI technology, the author(s) meticulously reviewed and amended the content as required, ensuring its accuracy and completeness. The author(s) assume(s) complete accountability for the content of the

publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

(2023), “Absorptive Capacity and Knowledge Appropriation”, Mendeley Data, V1, doi: 10.17632/3djyh62cz8.1.

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References

Al-Eisawi, D., Serrano, A., Koulouri, T., 2020. The effect of organisational absorptive capacity on business intelligence systems efficiency and organisational efficiency. *Ind. Manag. Data Syst.* <https://doi.org/10.1108/IMDS-02-2020-0120>.
 Alnuaimi, T., George, G., 2015. Appropriability and the retrieval of knowledge after spillovers. *Strateg. Manag. J.* 37 (7), 1263–1279. <https://doi.org/10.1002/smj.2383>.
 Amoroso, S., Audretsch, D.B., 2022. The role of gender in linking external sources of knowledge and R&D intensity. *Econ. Innov. New Technol.* 31 (1–2) <https://doi.org/10.1080/10438599.2020.1844038>. Article 1-2. Scopus.

- Arbussa, A., Coenders, G., 2007. Innovation activities, use of appropriation instruments and absorptive capacity: evidence from Spanish firms. *Res. Policy* 36 (10), 1545–1558. <https://doi.org/10.1016/j.respol.2007.04.013>.
- Armstrong, C.E., Lengnick-Hall, C.A., 2013. The Pandora's box of social integration mechanisms: can they make it more difficult to realize absorptive capacity. *J. Strategy Manag.* 6 (1), 4–26. <https://doi.org/10.1108/17554251311296530>.
- Behera, S.R., 2015. Do domestic firms really benefit from foreign direct investment? the role of horizontal and vertical spillovers and absorptive capacity. *J. Econ. Dev.* 40 (2). Article 2.
- Bahemia, H., Squire, B., Cousins, P., 2017. A multi-dimensional approach for managing open innovation in NPD. *Int. J. Oper. Prod. Manag.* 37 (10), 1366–1385. <https://doi.org/10.1108/IJOPM-07-2015-0415>.
- Bahl, M., Lahiri, S., Mukherjee, D., 2021. Managing internationalization and innovation tradeoffs in entrepreneurial firms: Evidence from transition economies. *J. World Bus.* 56 (1) <https://doi.org/10.1016/j.jwb.2020.101150>, 101150–101150.
- Barros, H.M., 2021. Neither at the cutting edge nor in a patent-friendly environment: appropriating the returns from innovation in a less developed economy. *Res. Policy* 50 (1). <https://doi.org/10.1016/j.respol.2020.104097>, 104097–104097.
- Bianchi, M., Croce, A., Dell'Era, C., Di Benedetto, C., Frattini, F., 2016. Organizing for inbound open innovation: how external consultants and a dedicated R&D unit influence product innovation performance. *J. Prod. Innov. Manag.* 33 (4), 492–510. <https://doi.org/10.1111/jpim.12302>.
- Bierly III, P., Chakrabarti, A., 2001. Dynamic knowledge strategies and industry fusion. *IJMTM* 3, 31–48. <https://doi.org/10.1504/IJMTM.2001.001394>.
- Bornkessel, S., Bröring, S., Omta, O., 2015. Crossing industrial boundaries at the pharmaceutical interface in probiotics: A life cycle perspective. *PharmaNutrition*. <https://doi.org/10.1016/j.phanu.2015.10.002>.
- Bosch, J.R., & Grobbelaar, S.S., 2021. The convergence of innovation systems and complex adaptive systems: a bibliometric analysis. In: Proceedings of the 30th International Conference of the International Association for Management of Technology, IAMOT 2021 - MOT for the World of the Future, 1382–1392. <https://doi.org/10.52202/060557-0108>.
- Cao, L., Li, L., Wu, Y., Zeng, W., 2020. Does industrial convergence promote regional metabolism? Evidence from China. *J. Clean. Prod.* 273, 123010 <https://doi.org/10.1016/j.jclepro.2020.123010>.
- Castaneda, D.I., Cuéllar, S., 2021. Knowledge sharing in business education. *Sustainable* 13 (7). <https://doi.org/10.3390/su13073657>. Article 7.
- Cepeda-Carrion, I., Martelo-Landroguez, S., Leal-Rodríguez, A.L., Leal-Millán, A., 2017. Critical processes of knowledge management: an approach toward the creation of customer value. *Eur. Res. Manag. Bus. Econ.* 23 (1) <https://doi.org/10.1016/j.iedeen.2016.03.001>. Article 1.
- Chanchetti, L.F., Oviedo Diaz, S.M., Milanez, D.H., Leiva, D.R., de Faria, L.I.L., Ishikawa, T.T., 2016. Technological forecasting of hydrogen storage materials using patent indicators. *Int. J. Hydrogen Energy* 41 (41), 18301–18310. <https://doi.org/10.1016/j.ijhydene.2016.08.137>.
- Chaparro, X., Kozesinski, R., Camargo, A., 2021. Absorptive capacity in startups: a systematic literature review. *J. Entrep. Manag. Innov.* 17 (1) <https://doi.org/10.7341/20211712>. Article 1.
- Chen, M.-N., Chang, Y.-C., 2019. Absorptive capacity, appropriability depth and new product development in Taiwanese service firms. *Asian J. Technol. Innov.* 27 (1), 108–133. <https://doi.org/10.1080/19761597.2019.1595688>.
- Chen, Y., Shen, L., Zhang, X., Chen, Y., 2022. Industry convergence and value innovation: A bibliometric analysis and systematic review. *Kybernetes*. <https://doi.org/10.1108/K-01-2022-0097>.
- Cheng, J.H., Chen, M.C., Huang, C.M., 2014. Assessing inter-organizational innovation performance through relational governance and dynamic capabilities in supply chains. *Supply Chain Manag. - Int. J.* 19 (2), 173–186. <https://doi.org/10.1108/SCM-05-2013-0162>.
- Chung, E., Lee, K., 2020. The necessity of anterior knowledge exchange activities for technological collaboration and innovation performance improvement. *Int. J. Technol. Manag.* 82 (1), 66–96. <https://doi.org/10.1504/IJTM.2020.107410>.
- Ciomaga, B., 2015. Convergence challenges in sport-related applied disciplines: the case of sport management. *Quest* 67 (3). <https://doi.org/10.1080/00336297.2015.1048374>. Article 3.
- Cohen, W.M., Levinthal, D.A., 1989. Innovation and learning: the two faces of R & D. *Econ. J.* 99 (397) <https://doi.org/10.2307/2233763>, 569–569.
- Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. *Adm. Sci. Q.* 35 (1) <https://doi.org/10.2307/2393553>. Article 1.
- Cohen, W.M., Goto, A., Nagata, A., Nelson, R.R., Walsh, J.P., 2002. R&D spillovers, patents and the incentives to innovate in Japan and the United States. *Res. Policy* 31 (8–9). [https://doi.org/10.1016/S0048-7333\(02\)00068-9](https://doi.org/10.1016/S0048-7333(02)00068-9).
- Colombelli, A., Grilli, L., Minola, T., Mrkajic, B., 2020. To what extent do young innovative companies take advantage of policy support to enact innovation appropriation mechanisms. *Res. Policy* 49 (10). <https://doi.org/10.1016/j.respol.2019.05.006>, 103797–103797.
- Cuellar, S., Grisales, S., Castaneda, D.I., 2023. Constructing tomorrow: a multifaceted exploration of Industry 4.0 scientific, patents, and market trend. *Autom. Constr.* 156, 105113 <https://doi.org/10.1016/j.autcon.2023.105113>.
- Cuellar, S.D., Fernandez-Bajón, M.T., Moya-Anegón, F. de, 2022. Similarities and differences between absorptive capacity and appropriability: a bibliometric perspective. *Benchmark. Int. J., Ahead-Print (Ahead-Print.)* <https://doi.org/10.1108/BLJ-12-2021-0773>.
- Curran, C.-S., Leker, J., 2011. Patent indicators for monitoring convergence – examples from NFF and ICT. *Technol. Forecast. Soc. Change* 78 (2), 256–273. <https://doi.org/10.1016/j.techfore.2010.06.021>.
- Curran, C.-S., Bröring, S., Leker, J., 2010. Anticipating converging industries using publicly available data. *Technol. Forecast. Soc. Change* 77 (3), 385–395. <https://doi.org/10.1016/j.techfore.2009.10.002>.
- Da Silva, C.R., Teixeira, A.A.C., 2012. Mapping local political entrepreneurship in Portugal. *Revista Portuguesa de Estudos Regionais* 31 (1). Scopus.
- de Almeida, B.P., Goncalves, E., da Silva, A.S., Reis, R.C., 2021. Internalization of knowledge spillovers by regions: A measure based on self-citation patents. *Ann. Res. Sci.* 66 (2) <https://doi.org/10.1007/s00168-020-01022-1>.
- de las Heras Rosas, C.J., Ballesteros, J., 2021. Research Trends in Open Innovation and the Role of the University. *Journal of Open Innovation Technology Market and Complexity* 7. <https://doi.org/10.3390/joitmc7010029>.
- Dedrick, J., Kraemer, K., Linden, G., 2010. Who profits from innovation in global value chains?: A study of the iPod and notebook PCs. *Ind. Corp. Change* 19 (1). <https://doi.org/10.1093/icc/dtp032>. Article 1.
- Deeds, D.L., 2001. Role of R&D intensity, technical development and absorptive capacity in creating entrepreneurial wealth in high technology start-ups. *J. Eng. Technol. Manag. - JET-M* 18 (1), 29–47. [https://doi.org/10.1016/S0923-4748\(00\)00032-1](https://doi.org/10.1016/S0923-4748(00)00032-1).
- Du, J., Lu, J., Guo, Y., 2015. Relationship between technological diversification of social network and technological innovation performance: empirical evidence from China. *Sci. Technol. Soc.* 20 (1), 60–88. <https://doi.org/10.1177/0971721814561388>.
- Duan, Y., Guan, Q., 2021. Predicting potential knowledge convergence of solar energy: bibliometric analysis based on link prediction model. *Scientometrics* 126 (5). <https://doi.org/10.1007/s11192-021-03901-6>. Article 5.
- Duan, Y., Wang, W., Zhou, W., 2020. The multiple mediation effect of absorptive capacity on the organizational slack and innovation performance of high-tech manufacturing firms: evidence from Chinese firms. *Int. J. Prod. Econ.* 229, 107754 <https://doi.org/10.1016/j.ijpe.2020.107754>.
- Dushnitsky, G., Lenox, M.J., 2005. When do incumbents learn from entrepreneurial ventures?: Corporate venture capital and investing firm innovation rates. *Res. Policy* 34 (5), 615–639. <https://doi.org/10.1016/j.respol.2005.01.017>.
- Egbetokun, A., Savin, I., 2012. Absorptive Capacity and Innovation: When Is It Better to Cooperate? *J. Evol. Econ.* 24 (2) <https://doi.org/10.1007/s00191-014-0344-x>.
- Elango, B., 2019. Calculation errors in bibliometrics: the case of CAGR. *COLLNET J. Scientometr. Inf. Manag.* 13 (2), 331–337. <https://doi.org/10.1080/09737766.2019.1694397>.
- Ernst, H., 1997. The use of patent data for technological forecasting: the diffusion of CNC-technology in the machine tool industry. *Small Bus. Econ.* 9 (4) <https://doi.org/10.1023/A:1007921808138>. Article 4.
- Escribano, A., Fosfuri, A., Tribó, J.A., 2009. Managing external knowledge flows: the moderating role of absorptive capacity. *Res. Policy* 38 (1), 96–105. <https://doi.org/10.1016/j.respol.2008.10.022>.
- Fu, S., Lai, C.-H., 2020. Are we moving towards convergence or divergence? Mapping the intellectual structure and roots of online social network research. *J. Comput. -Mediat. Commun.* 25, 111–128. <https://doi.org/10.1093/jcmc/zmz020>.
- Gimenez-Fernandez, E.M., Ferraris, A., Troise, C., Sandulli, F.D., 2022. Openness strategies and the success of international entrepreneurship. *Int. J. Entrepreneurial Behav. Res.* 28 (4) <https://doi.org/10.1108/IJEBR-09-2021-0745>. Scopus.
- Hacklin, F., Wallin, M.W., Björkdahl, J., von Krogh, G., 2021. The making of convergence: knowledge reuse, boundary spanning, and the formation of the ICT industry. *IEEE Trans. Eng. Manag.* 1–13. <https://doi.org/10.1109/TEM.2021.3087365>.
- Hannigan, T.R., Seidel, V.P., Yakis-Douglas, B., 2018. Product innovation rumors as forms of open innovation. *Res. Policy* 47 (5), 953–964. <https://doi.org/10.1016/j.respol.2018.02.018>.
- Harhoff, D., 1996. *Strategic Spillovers and Incentives for Research and Development*. *Manag. Sci.* 42 (6), 907–925.
- Heo, P.S., Lee, D.H., 2019. Evolution patterns and network structural characteristics of industry convergence. *Struct. Change Econ. Dyn.* 51, 405–426. <https://doi.org/10.1016/j.strueco.2019.02.004>.
- Hervas-Oliver, J.-L., Alborns Garrigos, J., Gil-Pechuan, I., 2011. Making sense of innovation by R&D and non-R&D innovators in low technology contexts: A forgotten lesson for policymakers. *Technovation* 31 (9), 427–446. <https://doi.org/10.1016/j.technovation.2011.06.006>.
- Hirsch, J.E., 2007. Does the h index have predictive power? *Proc. Natl. Acad. Sci. USA* 104 (49), 19193–19198. <https://doi.org/10.1073/pnas.0707962104>.
- Holgerson, M., Granstrand, O., Bogers, M., 2018. The evolution of intellectual property strategy in innovation ecosystems: Uncovering complementary and substitute appropriability regimes. *Long. Range Plan.* 51 (2), 303–319. <https://doi.org/10.1016/j.lrp.2017.08.007>.
- Hurmelinna-laukkanen, P., Puumalainen, K., 2013. Innovation performance in the shadow of expropriability — interplay of the appropriability regime and competitors' absorptive capacity. *Int. J. Innov. Technol. Manag.* 10 (01), 1–22. <https://doi.org/10.1142/s0219877013500028>.
- Hurmelinna-Laukkanen, P., 2012a. Constituents and outcomes of absorptive capacity – appropriability regime changing the game. *Manag. Decis.* 50 (7) <https://doi.org/10.1108/00251741211246950>. Article 7.
- Hurmelinna-Laukkanen, P., 2012b. Constituents and outcomes of absorptive capacity – appropriability regime changing the game. *Manag. Decis.* 50 (7), 1178–1199. <https://doi.org/10.1108/00251741211246950>.
- Hurmelinna-Laukkanen, P., 2014. Appropriability regimes in the international playground for innovation. *Eur. J. Int. Manag.* 8 (6), 621–643. <https://doi.org/10.1504/EJIM.2014.064898>.
- Ibrahim, A.E.A., Elamer, A.A., Ezat, A.N., 2021. The convergence of big data and accounting: Innovative research opportunities. *Technol. Forecast. Soc. Change* 173, 121171. <https://doi.org/10.1016/j.techfore.2021.121171>.

- Jeong, S., Kim, J.-C., Choi, J.Y., 2015. Technology convergence: what developmental stage are we in. *Scientometrics* 104. <https://doi.org/10.1007/s11192-015-1606-6>.
- Killick, R., Fearnhead, P., Eckley, I.A., 2012. Optimal detection of changepoints with a linear computational cost. *J. Am. Stat. Assoc.* 107, 1590–1598. <https://doi.org/10.1080/01621459.2012.737745>.
- Kim, T.S., Sohn, S.Y., 2020. Machine-learning-based deep semantic analysis approach for forecasting new technology convergence. *Technol. Forecast. Soc. Change* 157, 120095. <https://doi.org/10.1016/j.techfore.2020.120095>.
- Kim, Y.J., Lee, D.H., 2021. Technology convergence on automotive lightweight materials: evidence from South Korea. *Technol. Anal. Strateg. Manag.* 0 (0), 1–16. <https://doi.org/10.1080/09537325.2021.1973666>.
- Klarin, A., Suseno, Y., Lajom, J.A.L., 2021. Systematic literature review of convergence: a systems perspective and re-evaluation of the convergence process. *IEEE Trans. Eng. Manag.* <https://doi.org/10.1109/TEM.2021.3126055>.
- Kokshagina, O., Le Masson, P., Bories, F., 2017. Fast-connecting search practices: on the role of open innovation intermediary to accelerate the absorptive capacity. *Technol. Forecast. Soc. Change* 120, 232–239. <https://doi.org/10.1016/j.techfore.2017.02.009>.
- Lane, P.J., Koka, B.R., Pathak, S., 2006. The reification of absorptive capacity: a critical review and rejuvenation of the construct. *Acad. Manag. J.* 31 (4), 833–863. <https://doi.org/10.2307/20159255>.
- Liu, J., Chang, H., Forrest, J.Y.-L., Yang, B., 2020. Influence of artificial intelligence on technological innovation: Evidence from the panel data of China's manufacturing sectors. *Technol. Forecast. Soc. Change* 158. <https://doi.org/10.1016/j.techfore.2020.120142>, 120142–120142.
- Luan, C., Deng, S., Porter, A.L., Song, B., 2021. An approach to construct technological convergence networks across different IPC hierarchies and identify key technology fields. *IEEE Trans. Eng. Manag.* 1–13. <https://doi.org/10.1109/TEM.2021.3120709>.
- Lyu, C., Peng, C., Yang, H., Li, H., Gu, X., 2022. Social capital and innovation performance of digital firms: serial mediation effect of cross-border knowledge search and absorptive capacity. *J. Innov. Knowl.* 7 (2) <https://doi.org/10.1016/j.jik.2022.100187>.
- Malik, T.H., 2019. Society-nature-technology (SNT) nexus: institutional causes and cures of national morbidities. *Technol. Forecast. Soc. Change* 146, 491–503. <https://doi.org/10.1016/j.techfore.2018.04.027>.
- Malik, T.H., Xiang, T., Huo, C., 2021. The transformation of national patents for high-technology exports: Moderating effects of national cultures. *Int. Bus. Rev.* 30 (1) <https://doi.org/10.1016/j.ibusrev.2020.101771>. Article 1.
- Marcin, K., 2008. How does FDI inflow affect productivity of domestic firms? The role of horizontal and vertical spillovers, absorptive capacity and competition. *J. Int. Trade Econ. Dev.* 17 (1) <https://doi.org/10.1080/09638190701728131>. Article 1.
- Martin, S., 2002. Spillovers, Appropriability, and R&D. *Journal of Economics*. <https://www.jstor.org/stable/41794929?seq=1>.
- Martinez-Noya, A., Garcia-Canal, E., 2018. Location, shared suppliers and the innovation performance of R&D outsourcing agreements. *Ind. Innov.* 25 (3) <https://doi.org/10.1080/13662716.2017.1329085>.
- Milesi, D., Petelski, N., Verre, V., 2013. Innovation and appropriation mechanisms: Evidence from Argentine microdata. *Technovation* 33 (2–3), 78–87. <https://doi.org/10.1016/j.technovation.2012.12.001>.
- Miroshnychenko, I., Strobl, A., Matzler, K., De Massis, A., 2021. Absorptive capacity, strategic flexibility, and business model innovation: empirical evidence from Italian SMEs. *J. Bus. Res.* 130, 670–682. <https://doi.org/10.1016/j.jbusres.2020.02.015>.
- Moutinho, J.D.A., Silva, L.F.D., 2021. Knowledge management in project management: mapping bibliographic convergence. *Knowl. Manag. Res. Pract.* <https://doi.org/10.1080/14778238.2021.1931502>.
- Moya, F., Chinchilla, Z., Herrero, V., Corera, E., Gonzalez, A., & Vargas, B., 2005. El índice h de Hirsh: Aportaciones a un debate. El profesional de la información. https://www.researchgate.net/publication/232324925_El_indice_h_de_Hirsh_aportaciones_a_un_debate.
- Mubarak, M.F., Petraite, M., 2020. Industry 4.0 technologies, digital trust and technological orientation: What matters in open innovation? *Technol. Forecast. Soc. Change* 161. <https://doi.org/10.1016/j.techfore.2020.120332>.
- O'Dwyer, M., O'Flynn, E., 2005. MNC-SME strategic alliances—a model framing knowledge value as the primary predictor of governance modal choice. *J. Int. Manag.* 11 (3) <https://doi.org/10.1016/j.intman.2005.06.006>. Article 3.
- Oliveira, M., Curado, C., Balle, A.R., Kianto, A., 2020. Knowledge sharing, intellectual capital and organizational results in SMES: are they related. *J. Intellect. Cap.* 21 (6) <https://doi.org/10.1108/JIC-04-2019-0077>. Article 6.
- Park, B.J., Lee, C.-Y., 2022. Does R&D cooperation with competitors cause firms to invest in R&D more intensively? Evidence from Korean manufacturing firms. *J. Technol. Transf. Scopus*. <https://doi.org/10.1007/s10961-022-09937-x>.
- Pietronudo, M.C., Del Gaudio, B.L., Leone, D., 2021. Cooperation strategy and industry convergence. Evidence in the Chinese banking market. *Technol. Anal. Strateg. Manag.* 0 (0), 1–14. <https://doi.org/10.1080/09537325.2021.2003323>.
- Popaitoon, S., Yanpiboon, T., Tapjarern, C., 2021. Absorptive capacity and NPD: salient issues in bipolar entrepreneurial SMEs. *J. Asia Bus. Stud.* 15 (5), 769–783. <https://doi.org/10.1108/JABS-03-2020-0095>.
- Popkova, E.G., Sergi, B.S., 2020. Human capital and AI in industry 4.0. Convergence and divergence in social entrepreneurship in Russia. *J. Intellect. Cap.* 21 (4), 565–581. <https://doi.org/10.1108/JIC-09-2019-0224>.
- Rosenberg, N., 1963. Technological change in the machine tool industry, 1840–1910. *J. Econ. Hist.* 23 (4), 414–443.
- Roud, V., Vlasova, V., 2020. Strategies of industry-science cooperation in the Russian manufacturing sector. *J. Technol. Transf.* 45 (3) <https://doi.org/10.1007/s10961-018-9703-3>. Article 3.
- Roy, I., Paul, S.B., 2022. Knowledge Spillovers and Productivity Growth: Role of Absorptive Capacity in the Indian Manufacturing Sector. *J. Ind. Compet. Trade* 22 (2). <https://doi.org/10.1007/s10842-022-00382-y>. Scopus.
- Sarsah, S.A., Tian, H.Y., Dogbe, C.S.K., Bamfo, B.A., Pomegbe, W.W.K., 2020. Effect of entrepreneurial orientation on radical innovation performance among manufacturing SMEs: the mediating role of absorptive capacity. *J. Strategy Manag.* 13 (4), 551–570. <https://doi.org/10.1108/JMSA-03-2020-0053>.
- Seo, R., 2020. Interorganizational learning for R&D consortium performance: a social capital perspective. *J. Knowl. Manag.* 24 (2), 395–414. <https://doi.org/10.1108/JKM-06-2019-0265>.
- Shmulewitz, A., Langer, R., Patton, J., 2006. Convergence in biomedical technology. *Nat. Biotechnol.* 24 (3) <https://doi.org/10.1038/nbt0306-277a>. Article 3.
- Sick, N., Bröring, S., 2022. Exploring the research landscape of convergence from a TIM perspective: a review and research agenda. *Technol. Forecast. Soc. Change* 175, 121321. <https://doi.org/10.1016/j.techfore.2021.121321>.
- Sick, N., Preschitschek, N., Leker, J., Bröring, S., 2019. A new framework to assess industry convergence in high technology environments. *Technovation* 84–85, 48–58. <https://doi.org/10.1016/j.technovation.2018.08.001>.
- Spulber, D.F., 2012. Tacit knowledge with innovative entrepreneurship. *Int. J. Ind. Organ.* 30 (6) <https://doi.org/10.1016/j.ijindorg.2012.07.004>. Scopus.
- Srivastava, M.K., Gnyawali, D.R., Hatfield, D.E., 2015. Behavioral implications of absorptive capacity: the role of technological effort and technological capability in leveraging alliance network technological resources. *Technol. Forecast. Soc. Change* 92, 346–358. <https://doi.org/10.1016/j.techfore.2015.01.010>.
- Sun, Y., Zhai, Y., 2018. Mapping the knowledge domain and the theme evolution of appropriability research between 1986 and 2016: a scientometric review. *Scientometrics* 116 (1). <https://doi.org/10.1007/S11192-018-2748-0>. Article 1.
- Teece, D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Res. Policy* 15 (6), 285–305. [https://doi.org/10.1016/0048-7333\(86\)90027-2](https://doi.org/10.1016/0048-7333(86)90027-2).
- Teece, D.J., 1988. Capturing Value from Technological Innovation: Integration, Strategic Partnering, and Licensing Decisions on JSTOR. *Strategic Management Journal*. <https://www.jstor.org/stable/25061095?seq=1>.
- Thomas, A., 2019. Convergence and digital fusion lead to competitive differentiation. *Bus. Process Manag. J.* <https://doi.org/10.1108/BPMJ-01-2019-0001>.
- Thomas, R., Wood, E., 2015. The absorptive capacity of tourism organisations. *Ann. Tour. Res.* 54, 84–99. <https://doi.org/10.1016/j.annals.2015.06.004>.
- Todorova, G., Durisin, B., 2007. Absorptive capacity: Valuing a reconceptualization. *Acad. Manag. Rev.* 32 (3), 774–786. <https://doi.org/10.5465/AMR.2007.25275513>.
- Toutanova, K., & Manning, C., 2002. Enriching the Knowledge Sources Used in a Maximum Entropy Part-of-Speech Tagger. <https://doi.org/10.3115/1117794.1117802>.
- van Eck, N.J., Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84 (2). <https://doi.org/10.1007/s11192-009-0146-3>.
- Vega-Jurado, J., Gutiérrez-Gracia, A., Fernández-de-Lucio, I., Manjarrés-Henríquez, L., 2008. The effect of external and internal factors on firms' product innovation. *Res. Policy* 37 (4), 616–632. <https://doi.org/10.1016/j.respol.2008.01.001>.
- Wang, L., Cheng, Y., 2021. Exploring a comprehensive knowledge map for promoting safety management research in the construction industry. *Eng. Constr. Archit. Manag.* 29 (4), 1678–1714. <https://doi.org/10.1108/ECAM-11-2020-0984>.
- Wang, L., Cheng, Y., Wang, Z., 2022. Risk management in sustainable supply chain: a knowledge map towards intellectual structure, logic diagram, and conceptual model. *Environ. Sci. Pollut. Res.* 29, 1–27. <https://doi.org/10.1007/s11356-022-22255-x>.
- Wu, S.M., Ding, X.H., Liu, R.H., Gao, H., 2021. How does IT capability affect open innovation performance? The mediating effect of absorptive capacity. *Eur. J. Innov. Manag.* 24 (1), 43–65. <https://doi.org/10.1108/EJIM-02-2019-0043>.
- Xiongfeng, P., Xianyou, P., Changyu, L., 2020. Study on the impact of Chinese government R & D funding on technological innovation. *J. Ind. Eng. Eng. Manag.* 34 (1) <https://doi.org/10.13587/j.cnki.jieem.2020.01.002>. Article 1.
- Zahra, S.A., George, G., 2002. Absorptive capacity: a review, reconceptualization, and extension. *Acad. Manag. Rev.* 27 (2) <https://doi.org/10.5465/AMR.2002.6587995>. Article 2.
- Zhou, Y., Dong, F., Kong, D., Liu, Y., 2019. Unfolding the convergence process of scientific knowledge for the early identification of emerging technologies. *Technol. Forecast. Soc. Change* 144, 205–220. <https://doi.org/10.1016/j.techfore.2019.03.014>.