



# Complementors as ecosystem actors: a systematic review

Alexandra Elena Carst<sup>1,2</sup> · Yimei Hu<sup>1</sup>

Received: 19 January 2023 / Accepted: 31 July 2023  
© The Author(s) 2023

## Abstract

As downstream actors providing innovations that enhance the value of the core proposition, complementors have been recognized as indispensable in many definitions of ecosystems. The increasing attention they have received in the past years demonstrates the concern to enrich our knowledge of complementors. With a hybrid approach of bibliometric and content analyses, this systematic literature review aims at a clearer understanding of complementors in an ecosystem setting. The findings confirm complementors' strategic role in enhancing the ecosystem's focal value proposition and impacting the ecosystem survival and success, more intensely since 2018. Several characteristics of complementors are also revealed. Despite autonomy being their most affirmed feature, an inconsistent understanding of complementors in different types of ecosystems is revealed. This study represents a pioneering attempt to systematically understand complementors as ecosystem actors through extant literature. Various research gaps in the extant ecosystem research were also identified, providing research directions in terms of complementors' cooperative interactions, strategies, and challenges in ecosystems.

**Keywords** Complementor · Complement · Complementarity · Complementary asset · Ecosystem · Bibliometric analysis

**JEL Classification** O32

## 1 Introduction

Ecosystems are the locus and structure where various loosely coupled actors interact to materialize (complex) value propositions (Adner and Kapoor 2010; Adner 2017; Kapoor 2018). Beyond the traditional interorganizational network literature, the ecosystem research stream emphasizes the complementors' participation in augmenting

---

✉ Yimei Hu  
yimei@business.aau.dk

<sup>1</sup> Aalborg University Business School, Aalborg University, Aalborg, Denmark

<sup>2</sup> Sino-Danish College (SDC), University of Chinese Academy of Sciences, Beijing, China

the focal value proposition (Tsujiimoto et al. 2018). Complementors are downstream actors whose output enhances the value of a focal product or service that customers generate from its use (Brandenburger and Nalebuff 1996). Neglecting complementors in an ecosystem may lead to the failure of the focal firm and the realization of the core value proposition (Adner 2021; Liang et al. 2022), as exemplified by the successful entry of Alfa Romeo and Fiat in the United States, only when specialized mechanics or appropriate spare parts were made available (Brandenburger and Nalebuff 1996).

Complementors' innovations and value-added activities, when bundled together with the focal firm's core offering, unlock the full-value potential of the core product, thereby improving the reputation and performance of the entire ecosystem (Teeco 1986; Brandenburger and Nalebuff 1996; Adner and Kapoor 2010). Complementors' innovations, role, and presence are thus deemed necessary for the focal firm and the entire ecosystem (Adner and Kapoor 2010; Brusoni and Prencipe 2013). Nevertheless, proper coordination of complementors seems to be overlooked (Liang et al. 2022). Furthermore, in a business world where cooptation, i.e., simultaneous cooperation and competition, is increasingly ubiquitous (Brandenburger and Nalebuff 1996; Bengtsson and Kock 1999, 2000), the power of differentiation and competitive advantage may lie in the hands of complementors (Mantovani and Ruiz-Aliseda 2016). Hence, understanding complementors and their interactions with other ecosystem actors is crucial.

In recent years, several reviews of various types of ecosystems have brought clarity and progress towards a theory of ecosystems (e.g., Cobben et al. 2022; Granstrand and Holgersson 2020; McIntyre and Srinivasan 2017; Rietveld and Schilling 2021; Shipilov and Gawer 2020; Tsujiimoto et al. 2018). However, complementors have not been the main focus of analysis until now. Despite receiving increasing academic attention in ecosystem research and being integrated into most definitions for (innovation) ecosystems (Jacobides et al. 2018), research on complementors in ecosystem settings remains dispersed across contexts and topics. Therefore, this review aims to clarify the development of complementors' research in the extant ecosystem literature, providing a comprehensive and in-depth understanding of their definitions, roles, and interactions within ecosystems. This systematic review investigates and synthesizes the state-of-the-art ecosystem literature to understand complementors as ecosystem actors. For this purpose, we relied on two methods: (1) A bibliometric analysis for an overview of the conceptual structure and development of the literature, and (2) A content analysis of the most relevant articles.

To the best of our knowledge, this review represents a pioneering and timely attempt to synthesize the extant literature on complementors in ecosystems. By providing a comprehensive understanding of complementors, the review makes several contributions to ecosystem literature. First, we identify the definitions, core features, and roles of complementors. Additionally, we provide an overview of their interactions, strategies, and challenges in different types of ecosystems. Among others, autonomy emerges as a commonly affirmed characteristic of complementors. Despite their primary role of value enhancement, complementors' relationships with other ecosystem actors are often cooptative. The intensity of these cooptative relationships determines the ecosystem's structure, health, and governance system

(Gawer 2014). For this reason, coordinating complementors presents a management challenge.

Second, we show the contribution and connection of interrelated concepts, i.e., complements, complementary assets, and complementarity, to the ecosystem literature. We emphasize the need for conceptual rigor regarding these terms in ecosystem studies and offer delimitations and suggestions for cautious use of these concepts in connection with complementors to avoid confusion.

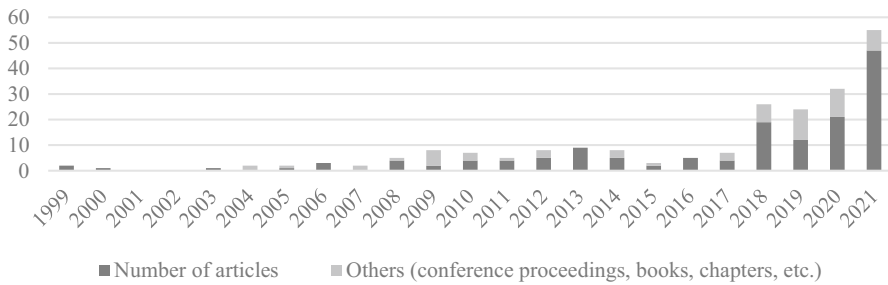
Third, we provide several research avenues that could enrich our knowledge of complementors as ecosystem actors. Due to the imbalance in the number of studies on complementors in different types of ecosystems, further research on these actors in other ecosystem types, besides platforms, is warranted.

## 2 Complementors: from game theory origin to ecosystem appropriation

With a game theory origin, complementors were first coined as a term in Brandenburger and Nalebuff's book "*Co-opetition*" (1996). Together with suppliers, customers, and competitors, complementors formed the proposed value net of the focal firm (ibid.). Until then, complementors were only regarded as value enhancers. Since the mid-1990s, the role of complementors has been attested as strategically vital to firms due to their ability to enlarge the business pie. "*A player is your complementor if your customers value your product more when they have the other player's product than when they have your product alone*" (Brandenburger and Nalebuff 1996, p. 18). However, complementors can also exhibit competitive tensions with other value co-creation actors (Brandenburger and Nalebuff 1996; Yoffie and Kwak 2006; Helfat and Raubitschek 2018). The fact that complementors and co-opetition have the same origin is not surprising. Rather than dividing the world into black and white, competitors and partners, co-opetition offers the potential for a win-win situation. The simultaneous presence of cooperation and competition dimensions has become the new normal (Brandenburger and Nalebuff 1996; Bengtsson and Kock 2000). The potential for value co-creation is followed by competitive tension and value destruction (Gnyawali and Charleton 2018). Therefore, complementors have also been referred to as a type of co-opetitors (Afuah 2000).

The concept of complementors was later adopted in ecosystem literature to define actors that add extra value through their innovations. Alongside complementarity, complementors became crucial notions in business ecosystem studies and were later endorsed in innovation and platform ecosystem research (Boudreau 2010; Srinivasan and Venkatraman 2010; Scholten and Scholten 2012; Tsujimoto et al. 2018), as "*ecosystem often takes a time to realize the benefits from complementors*" (Kang et al. 2011, p. 287). As illustrated in Fig. 1, the literature on complementors has seen a surge in recent years; possibly an attempt to clear up some confusion surrounding this concept (Teece 2018).

The products, activities, or services resulting from these complementarities are generally referred to as *complements* (Teece 1986, 2018). Failing to engage and coordinate with complementors can lead to the collapse of the focal firms' business



**Fig. 1** Evolution of complementor literature. The dataset was extracted from Web of Science and Scopus by searching the truncated keyword “*complementor\**”

(Adner and Kapoor 2010; Brusoni and Prencipe 2013; Mantovani and Ruiz-Aliseda 2016). Despite the wide variety of the complements and their impact on the attractiveness of other businesses’ products and success, complements are often overlooked. This prompted Teece (2018) to describe that “*the literature on complements is both confused and complex*” (p. 1373). Complementors may not generate all the types of complementarities, and third-party firms are not the only providers of complements. In some cases, focal firms may also internally produce complements,<sup>1</sup> but offer them as separate products to the customer. In this instance, the firm has a dual role of complementor and focal firm (Adner and Kapoor 2010; Gawer and Henderson 2007; Zhu and Liu 2018). Google, for instance, owns the Android platform (the focal firm) while acting as a complementor through its applications on Google Play Store.

To develop the ecosystem theory, the interdependencies and complementarities among ecosystem actors have been highlighted recently. Particularly, non-generic complementarities are seen as delineating elements of ecosystems (Jacobides et al. 2018; Kapoor 2018; Teece 2018). However, due to application heterogeneity and identical word stems, the use of concepts such as *complement*, *complementary innovation*, and *complementarity* seems to cause conceptual and terminological confusion (Adner 2017; Teece 2018). This confusion may undermine the notional and application utility of these terms. To avoid such threats, clarifications are necessary to improve their conceptual rigor in the ecosystem literature.

In the discussion about complementors, we can hardly avoid a more fundamental concept, complementarity, with an undeniable presence in ecosystems (Jacobides et al. 2018). The definitions of complementarity are versatile, depending on the area of study (Xu et al. 2010). In neoclassical economics, complementarity is perceived as the impact on user value, i.e., “*the marginal value of a variable increases with another variable*” (Teece 2018), or factor prices from the perspective of cross-price elasticity (Xu et al. 2010). While in innovation research, complementarity is seen as technological congruence and the synergistic interactions or effects resulted from

<sup>1</sup> In this study and from here onwards, we use *complements* as strictly referring to complementors’ output, unless otherwise specified.

combining or reconfiguring current technologies into novel solutions (Teece 1986, 2018; Xu et al. 2010). Despite its apparent conceptual simplicity, complementarity is a rather complex notion that is too “*complicated to understand fully*” (Samuelson 1974, p. 1255). For a non-exhaustive list of types of complementarities, consult Appendix 1.

Furthermore, complementarities and complementary assets are sometimes used interchangeably (Morgan et al. 2013). *Complementary assets* are a broad term that encompasses “*different types of complementary resources, capabilities, technologies, and activities that are required for the commercialization of a given core technology*” (Kapoor and Furr 2015, p. 417). According to Teece (1986), complementary resources and capabilities represent a main determinant in a firm’s strategic decisions intending to capture value. Originally, complementary assets were considered internal to a firm. However, with the development of the ecosystem stream, complementary assets crossed these boundaries by also encapsulating the complementary products and services delivered by third-party providers (Helfat and Raubitschek 2018).

As Adner (2017) also stated, in the ecosystem context, the concepts of complementors, complements, and complementary assets “*have suffered from a conceptual blending as improvements in any of these are treated as improving the focal firm’s offer in the same general way*” (p. 50). Thus, clarification and delimitation of these concepts are necessary. This literature review aims to elucidate and understand the features and differences of these concepts, i.e., complementors, complements, complementarity, complementary assets. In light of the overlaps among these concepts, which may go beyond sharing the same word stem, and the warning on conceptual blending, several questions arise: (1) What are complementors’ characteristics and roles in ecosystems? (2) How do complementors behave in ecosystems? and (3) How are the intersecting concepts understood in ecosystem literature? The review also identifies significant gaps in ecosystem research concerning complementors.

### 3 Methods

This study adopts a systematic review approach to provide reliable and evidence-informed findings with minimized bias. Conducting, structuring, and synthesizing the findings in a systematic manner render transparency, replicability, and consistency of the review process and results (Davis et al. 2014; Snyder 2019; Cobben et al. 2022). Given the relatively new research track and complex nature of ecosystems, a hybrid methodology combining bibliometric and content analyses is adequate to gain a comprehensive understanding of complementors. This approach involves a bibliometric analysis of the existing ecosystem literature and a qualitative analysis of the most relevant articles. The combination of bibliometric analysis techniques and content analysis method increases the reliability of the findings and facilitates our understanding of the conceptual structure of the reviewed articles. To ensure the reliability and objectivity of the

	Phase I		Phase II						Phase III					
Search string	Original		Group 1		Group 2		Group 3		FC		BC			
Database	S	W	S	W	S	W	S	W	S	W	S	W		
Results	136	80	7	5	31	13	12	3	355	887	845 <sup>a</sup>	837		
Types of document: article	69	75	5	4	22	12	8	3	260	812	83	762		
Language: English	69	75	4	3	22	12	7	3	256	811	83	761		
Relevant subject areas (Business, Management, Social Sciences, Economics)	61	62	4	3	12	8	7	3	230	600	83	550		
Relevancy + until 2021 including	59	61	4	3	8	7	6	3	108	82	83	38		
Dataset after removing duplicates	79		5		8		6		172		117			
Merged dataset			92 (= 69 W + 21 S)						172		117			
Final dataset									253					

**Fig. 2** Article selection and screening process for bibliometric analysis. Database S stands for Scopus, while W stands for Web of Science. Phase I original search string: *ecosystem\** AND *complementor\**. Phase II search strings: see Table 2. Phase III comprises two searches, i.e., forward citation (FC) and backward citation (BC). The S dataset for Phase III represent the 21 S merged dataset from Phase I and II, while W dataset is the 69 W merged dataset. Due to different filter options, the results were first limited to publications until 2021. Under the relevancy criterion, Phase III results were further filtered based on the inclusion of “*ecosystem\**” and “*complement\**” in topic fields. For backward citations in Scopus, this filter was applied earlier (point a) due limited options

review, transparent and reproducible steps were employed in the search strategy and selection of articles. Initially, we performed a bibliometric analysis to grasp and map the relevant extant knowledge using quantitative methods (Zupic and Čater 2015). Subsequently, a qualitative in-depth content analysis allowed for identification of themes in the most relevant articles in the dataset (Gaur and Kumar 2017).

### 3.1 Search strategy and data selection

This review relies on a collection of bibliographic data extracted from two multi-disciplinary databases, namely Web of Science and Scopus. The choice of these two major databases is due to their slightly different but overlapping coverage of journals. Relying on two databases is also motivated by the inclusion of all relevant articles in our dataset (Aria and Cuccurullo 2017; Gavel and Iselid 2008; Zhu and Liu 2020). Considering the narrow research focus and yet maturing field of ecosystem stream, the initial search string contained two truncated terms, “*ecosystem\** AND *complementor\**” (Phase I, as illustrated in Fig. 2), to capture the plurals. The combined dataset resulted in 79 unique English articles from relevant subject areas until 2021. After reading the content of these articles, alternative wordings and synonyms for complementors were identified and presented in Table 1. These additional terminologies were grouped based on similarity and used in a second search round

**Table 1** Identified alternative terminologies for complementors in the first resulted dataset from Phase I. The search strings of each group were used in Phase II as shown in Fig. 2

Group	Synonym/Alternative name for complementor(s)	Number of articles	Example of articles	Search string	Phase II of search
1	Complement producers	5	Rietveld et al. (2020), Rietveld and Eggers (2018), Rietveld and Schilling (2021); Winter et al. (2018)	“ecosystem*” AND (“complement producer*” OR “complement developer*” OR “complement provider*” OR “producer* of complement*” OR “developer* of complement*” OR “provider* of complement*”)	Group 1
1	(third-party) Complement developers	1	Rietveld and Shilling (2021)		
1	Providers of complements	1	Weiss and Gangadharan (2010)		
2	Complementary firms	2	Bagheri et al. (2016), Huo et al. (2021)	“ecosystem*” AND (“complementary firm*” OR “complementary manufacturer*” OR “complementary partner*” OR “complementary enterprise*” OR “complementary organization*”)	Group 2
2	Complementary partners	3	Williamson and De Meyer (2012), Thomas and Ritala (2021), Winter et al. (2018)		
2	Complementary manufacturers	1	Huo et al. (2021)		
2	Complementary enterprises	1	Huo et al. (2021)		
2	Complementary organizations	1	Thomas and Ritala (2021)		
3	Producers of complementary goods	2	Mantovani and Ruiz-Aliseda (2016), Rietveld and Eggers (2018)	“Ecosystem*” AND (“provider* of complementary*” OR “supplier* of complementary*” OR “developer* of complementary*” OR “producer* of complementary*”)	Group 3
3	Complementary goods producers	1	Rietveld and Schilling (2021)		
3	Providers of complementary products and services	2	Schmeiss et al. (2019), Rietveld and Eggers (2018)		
3	Providers of complementary goods	1	Rietveld and Eggers (2018)		
3	Suppliers of complementary goods	1	Rietveld and Eggers (2018)		
3	Third-party developers of complementary modules	1	Benlian et al. (2015)		

together with “ecosystem\*”, in Phase II. Generic terminologies, such as “third-party developers”, were excluded. This step enlarged the dataset to an aggregate of 92 unique articles. Lastly, to ensure the inclusion of relevant papers, a third round of dataset expansion with forward and backward cited articles was conducted (82 plus 38 from Web of Science, and 108 plus 83 from Scopus in Phase III). This step also minimized the probability of missing recent but contributing articles. Some of these articles might use only the term “*platform*” instead of “*platform ecosystem*”. Such publications were initially bypassed by the search strings due to the inclusion of the keyword “*ecosystem*”.

The focus on the overall ecosystem concept is justified by its shared fundament across all ecosystems (e.g., business ecosystems, innovation ecosystems, platform ecosystems, entrepreneurial ecosystems). A variety of ecosystem types emerged potentially from the lack of consensus on a core definition (Ritala and Almpantopoulou 2017). Nevertheless, the differentiation between business ecosystems and innovation ecosystems remains unclear in the literature (Gomes et al. 2018). Thus, this review uses the umbrella concept of ecosystem to provide an overview of the research development on complementors across different types of ecosystems.

At each search stage, the same exclusion criteria based on publication type, language, scientific disciplines, and relevancy were applied. Consequently, only academic articles written in English and published until the end of 2021 were selected. However, early access articles published in 2022 were also included. The search results were refined based on relevant subject areas, e.g., business, management, and social sciences. Before extractions, further data cleaning was performed. By reading the articles’ titles, abstracts, and keywords, we screened the articles based on relevant use of the term “*ecosystem*”. Only articles that refer to business-related ecosystems were included, e.g., business ecosystem, innovation ecosystems, platform ecosystems, digital ecosystems, entrepreneurial ecosystem. In this relevancy stage, we excluded all the articles that refer to other types of ecosystems, e.g., marine ecosystems, biological ecosystems, ecological ecosystems, agricultural ecosystems, or architectural ecosystems. Additionally, articles that used “*complement*” as a verb in an unrelated context were removed. In cases where such information was not available in the abstracts, the article’s content was read to determine its relevance. After extracting and merging the datasets to remove duplicates, 253 unique articles entered the bibliometric analysis. Two more special issue introductory articles were excluded. Figure 2 illustrates the selection process.

### 3.2 Bibliometric analysis

The final dataset for bibliometric analysis comprised 253 articles, as shown in Fig. 2. This method objectively served the purpose of this study. Bibliometric analysis also revealed critical information about the body of ecosystem literature involving, regarding, or mentioning complementors. A first, descriptive analysis of the bibliographic metadata was conducted. The data were harmonized by converting singulars into plurals (e.g., ecosystems, complementors, platforms, complements) to avoid double occurrences of the same keywords.



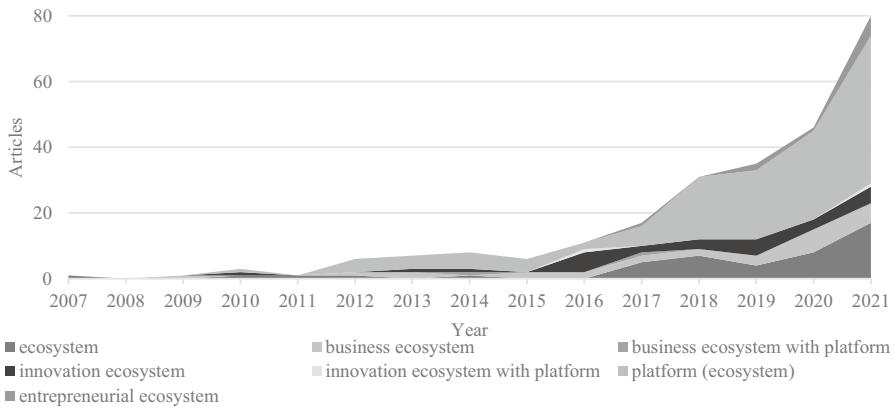
The bibliometric analysis focused on the conceptual structure to understand the main themes and trends regarding complementors in ecosystems. Relevant keywords were mapped to visualize their growth dynamics using bibliometrix package in RStudio (Aria and Cuccurullo 2017) and Excel. Further science mapping of the conceptual structure through co-word analysis was performed in RStudio and VOSviewer, revealing relationships and similarities between articles based on keyword co-occurrences (Su and Lee 2010; Zupic and Čater 2015; Aria and Cuccurullo 2017). We further generated conceptual thematic maps illustrating the centrality and density, as well as the evolution of topics that represent the dataset, providing insight into the research topics contained therein and revealing links between concepts or themes.

### 3.3 Content analysis

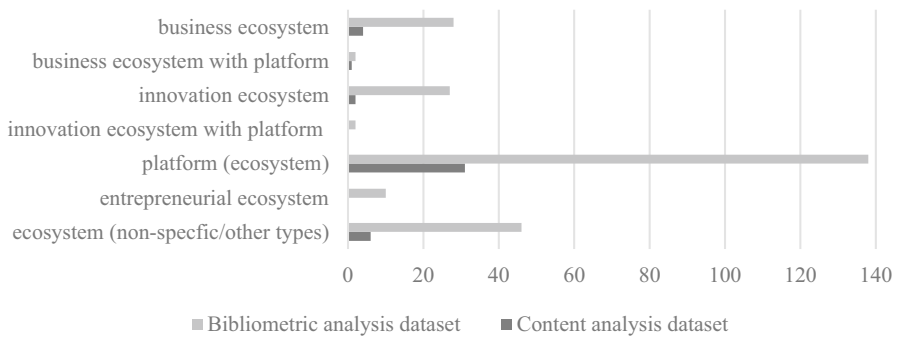
Bibliometric analysis provides an overview of the ecosystem research stream through a rigorous scientific process. However, it relies solely on bibliographic data for analysis, while the articles' contents are not taken into consideration. Therefore, a content analysis was performed to provide a more in-depth explanation of complementors within the relatively new context of ecosystems (Weber 1990; Duriau et al. 2007). This second analysis of the most influential studies offered a comprehensive understanding of the reviewed articles and trends. Similar to other reviews (e.g., Alon et al. 2018; Bretas and Alon 2021), the selection of articles was objectively performed by intersecting the most globally (at least 10 global citations) and most local referenced documents (at least 10 local citations), resulting in 44 articles for the content analysis. As the selected articles may not all take the perspective of complementors but still provide relevant information, the content of the 44 articles was thoroughly read and systematically reviewed. The articles were coded in NVivo, a qualitative data analysis software, to uncover relevant themes in connection to complementors as detailed in Sect. 5. The codes were delimited by the ecosystem type that set the scene in the 44 articles, allowing for the identification of variations in perceptions and understanding of complementors in different settings. The codes were grouped into categories to generate the main themes. For an overview of the articles included in content analysis, see Appendix 2.

### 3.4 Descriptive analysis

The dataset for bibliometric analysis spanned over 14 years from 2007 to 2021, consisting of articles written by 524 authors and published in 107 journals, with a compound annual growth rate of 40.08% in scientific production. Multi-authored articles dominated the sample, accounting for 217 articles. As illustrated in Fig. 3, the research agenda on complementors received increasing academic attention from 2012 onwards, with an initial peak in 2010. This peak is likely attributed to Adner and Kapoor's seminal work on value creation and interdependence in innovation ecosystems (2010), which triggered subsequent upsurges. Innovation



**Fig. 3** Annual scientific production by ecosystem type



**Fig. 4** Categorization of articles based on the types of ecosystems studied in the two datasets

ecosystem-based studies dominated in 2016, but since 2017, research on platform (ecosystems) has been the leading setting to study complementors.

The year 2018 presents the first noticeable apogee, marking a turning point that renders greater academic attention. The 2018 studies contributed with attempts to theorize and conceptualize different types of ecosystems (Helfat and Raubitschek 2018; Jacobides et al. 2018; Kapoor 2018; Teece 2018) and numerous case studies, particularly on platform ecosystems, contributing to understanding complementors (e.g., Cennamo 2018; Inoue and Tsujimoto 2018; Karhu et al. 2018; Ozalp et al. 2018; Rietveld and Eggers 2018; Zhu and Liu 2018). Since 2018, there has been a constant increase in annual publication output, particularly in platform ecosystem empirical studies.

The articles included in the dataset covered various types of ecosystems. Complementors in platform ecosystems are the most frequently studied (e.g., Benlian et al. 2015; Boudreau 2012; Boudreau and Jeppesen 2015; Cenamor et al. 2013; Cennamo 2018; Gawer 2014), while complementors in entrepreneurial ecosystems are the most disregarded. Figure 4 exposes the uneven development of complementor

**Table 2** Research design of the articles included in the bibliometric and content analyses

Research design	Bibliometric analysis dataset		Content analysis dataset	
	Number of papers	Percentage (%)	Number of papers	Percentage (%)
Empirical study	165	65.22	28	63.64
Qualitative	63	24.90	2	4.55
Quantitative	82	32.41	21	47.73
Mixed methods	20	7.91	5	11.36
Conceptual/theoretical	36	14.23	7	15.91
Conceptual/theoretical paper + empirical study/ simulation	8	3.16	0	0
Literature review	28	11.07	5	11.36
Experiment/modelling	12	4.74	1	2.27
Experiment/modeling + empirical study/ simulation	4	1.58	3	6.82
	<b>253</b>	<b>100</b>	<b>44</b>	<b>100</b>

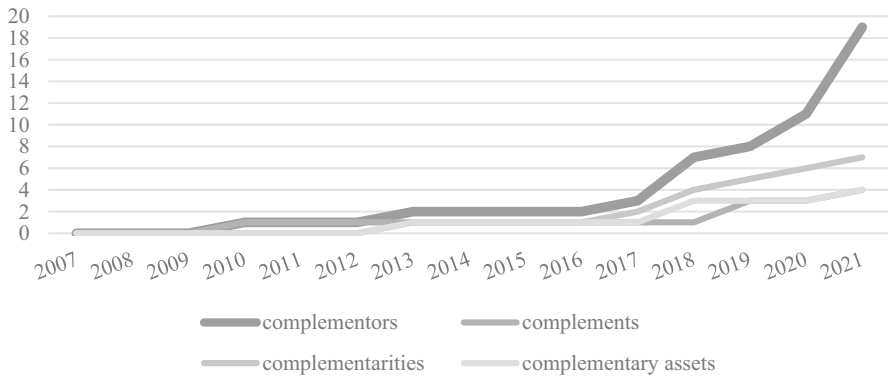
research across different types of ecosystems. The division of articles by ecosystem type is maintained across the 44 articles in the content analysis.

Most of the articles in the dataset are empirical studies, with quantitative studies dominating. The remaining articles comprise conceptual or theoretical publications, literature reviews, and experiments or modelling, in descending order. Table 2 illustrates similar disproportion in research design captured by the two datasets. The reliance on empirical studies is understandable, given the still-developing ecosystem research seeking theorization of the field. The presence of several literature reviews also justifies the pursuit of clarity and structure in the ecosystem field. Synthesizing and integrating existing literature pave the way to a deeper understanding of definitions, origins, development, key challenges of ecosystems, and research directions (e.g., De Reuver et al. 2018; Nambisan et al. 2018; Thomas et al. 2014; Tsujimoto et al. 2018). However, to the best of our knowledge, this is the first attempt to systematically review complementors.

## 4 Bibliometric analysis

### 4.1 Keywords' growth trends

Examining the yearly cumulative occurrences, *complementors* resurfaced as an author's keyword in ecosystem-related studies in 2010. Figure 5 depicts an ascending trend after 2017, indicating the increasing academic interest in complementors as ecosystem actors. This phenomenon can be attributed to the upsurge of ecosystem studies that notice and/or regard complementors as undisputable actors (e.g.,



**Fig. 5** Cumulative keywords' growth trends

Cennamo et al. 2018; Kapoor and Agarwal 2017; Rietveld and Eggers 2018; Zhu and Liu 2018).

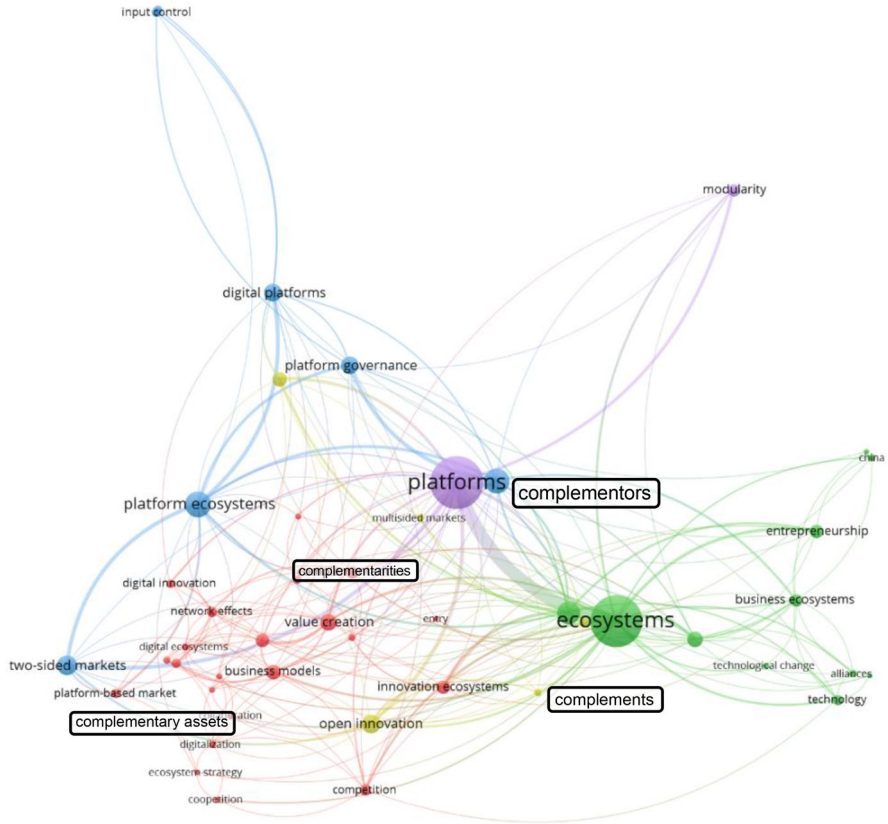
Complementors' products and services emerged as a top author's keywords under the terminology of *complements* in 2010, the same year as *complementors*. From 2013 onwards, *complementary assets* and *complementarities* also emerged as keywords, reflecting their importance in sustaining the ecosystem research track. However, the dynamics of these keywords have shown a slowdown in the usage rate recently. In contrast, the keyword *complementors* has accelerated since 2018, significantly distancing itself from the other keywords.

## 4.2 Conceptual structure

### 4.2.1 Keyword co-occurrence analysis

Through co-word network analysis of the dataset, the conceptual structure of knowledge can be mapped. This analysis captures relationships between relevant concepts based on their co-occurrence in a set of articles. By relying on author's keywords as a method parameter, important and emerging topics are uncovered. The size of the node represents the frequency of the keyword. Figure 6 exhibits two dominant clusters, representing *platforms* (purple) and the umbrella concept of *ecosystems* (green). The emergence of *platforms* and *platform ecosystems* (blue) in two clusters is not surprising, given the increasing preference for using only *platforms*. It, thus, illustrates the detachment of platform studies from the ecosystem stream and establishing its own arena.

*Complementors* emerged as a distinct keyword under the platform ecosystems cluster (blue). Under this cluster, *complementors* heavily link to *platform governance*, showcasing their critical role in a platform ecosystem setting. However, *complementors* also strongly connect with concepts from other clusters, such as *business ecosystems*, *platforms*, *ecosystems*, and *innovation*. Additionally, weaker links of *complementors* include *complement quality*, *digital transformation*, *competition*,

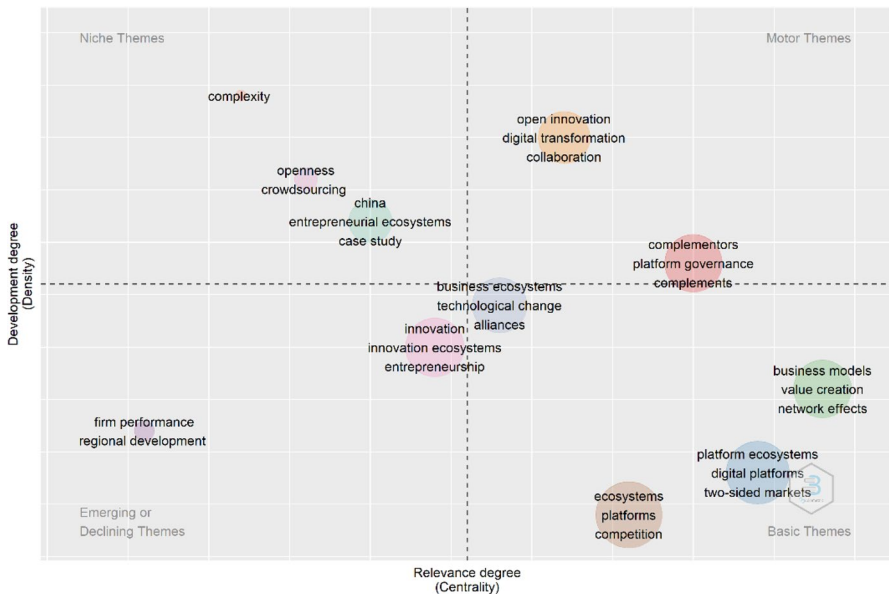


**Fig. 6** Co-occurrence network based on author’s keywords

specifically *platform competition*, *sustainability*, *modularity*, and *governance*. These topics comprise potential research avenues in connection to complementors.

While *complements* materialized as a topic under the *open innovation* cluster, it connects with all other clusters. Thus, *complements* seem to contribute to a wide range of topics, e.g., *ecosystems*, *business ecosystems*, *platforms (ecosystem)*, *platform governance*, *value creation*, and *value capture*.

Unlike *complementors* and *complements*, *complementarities* and *complementary assets* emerged under the same cluster (red), but without a direct link. Besides *ecosystems*, the contribution of *complementary assets* is primarily limited to the cluster it belongs to, i.e., *dynamic capabilities*, *value creation*, *value capture*, *business models*, and *network effects*. In contrast, *complementarities* appeared more versatile, contributing to several research fronts, particularly related to platform (ecosystems), but also ecosystems. Specifically, *complementarity* connected with *platform (ecosystems)*, *digital platforms*, *ecosystems*, *strategy*, *value creation*, *network effects*, *platform competition*, *complement quality*, and further with *modularity*.



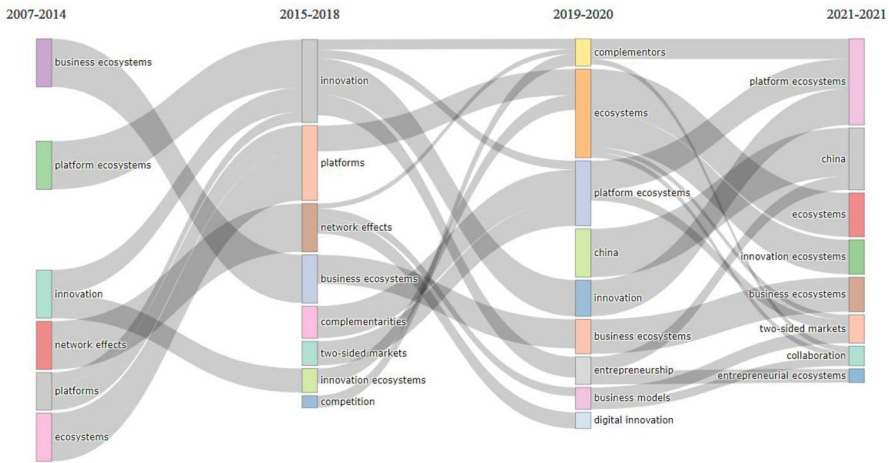
**Fig. 7** Thematic map (The top term of each node is the dominant keyword.)

The lack of direct links among *complementors*, *complements*, *complementary assets*, and *complementarity* exposes the need for connecting research. The disjunction between these topics confirms Adner's argument (2017). Jointly exploring these concepts may reveal overlaps and discrepancies to better understand their individual contribution to the ecosystem field.

#### 4.2.2 Thematic analysis

Thematic analysis is a method of plotting connections on a two-dimensional matrix based on density and centrality functions. Density refers to the theme's development, while centrality captures its importance in a specific field (Aria and Cuccurullo 2017). Figure 7 illustrates the thematic analysis of the dataset. The node size indicates the number of keywords captured by the respective topic. The upper right quadrant depicts the motor themes that lead the literature, with high density and high centrality. These "driving" topics mainly include *open innovation* and *complementors*. It should be noted that the lower development degree of *complementors* determines its crossing into the basic themes' quadrant. This explains the research potential of *complementors* that is left unexplored in ecosystem literature.

The upper left quadrant displays niche themes that lack strong representation in the dataset. Themes such as *complexity* and *entrepreneurial ecosystems* require further development in connection with *complementors*. The lower left quadrant of emerging or declining themes includes topics like *firm performance* and *innovation (ecosystems)*. The umbrella concept of *ecosystems*, along with *business models* and *platform ecosystems*, appears as a basic theme in the lower right quadrant. Due to a lower centrality,



**Fig. 8** Thematic evolution with four time slices

*innovation ecosystems* also transverse into basic themes. These topics show a high degree of relevance to be researched further.

### 4.2.3 Thematic evolution

Thematic evolution is a method that divides a given period into time intervals and charts the evolution of themes across time. In this study, the inclusion index weighted by author's keyword occurrences, with a minimum frequency of five, was utilized to map the research field into an alluvial graph. Three cutting years were chosen based on the most notable yearly surges of publication, as shown in Fig. 5. Figure 8 displays the longitudinal thematic map with different representative themes for each period. Each term corresponds to a topic that can converge into another mainstream theme over time or diverge into multiple themes.

*Complementors* emerged as a top theme in the third time slice (2019–2020), stemming from three themes: *innovation*, *network effects*, and *competition*. Complementor's incremental innovations, i.e., complements, create indirect network effects that benefit the entire ecosystem. Despite their collaborative nature in enhancing the core offering's value, complementors' link with the *competition* theme is not unexpected, given their initial definition involving “*some inherent [competitive] tensions*” (Brandenburger and Nalebuff 1996, p. 17). Since 2021, *complementors* have been mainly captured by *platform ecosystems* research, emphasizing their integral role in platforms.

### 4.3 Key findings of bibliometric analysis

As a keyword, *complementors* have been increasingly used in ecosystem literature, particularly since 2018. However, terms with the same word stem show a lower usage rate.

The conceptual structure mapped through keyword co-occurrence analysis revealed strong links between complementors and platform and business ecosystem streams, as well as platform governance. Complementors in other types of ecosystems, such as innovation ecosystems, require further exploration. The weaker links with (platform) competition, complement quality, sustainability, modularity, and governance present areas for future research. Additionally, the disconnect between complementors, complements, complementary assets, and complementarity suggests the need for bridging research.

The thematic analysis indicates that complementors in ecosystems is a topic that requires further development, particularly in connection with entrepreneurial ecosystems and the competition dimension. Although the thematic evolution shows the contribution of competition research to complementors studies, complementors have mainly been captured by platform research since 2021.

## 5 Content analysis

After coding the 44 selected articles by ecosystem type, several major themes emerged: (1) Definitions, characteristics, and roles of complementors; (2) Complementors' interactions, participation determinants, challenges, and strategies; (3) Complements and complementary assets; and (4) Complementarity.

### 5.1 Complementors: definitions, characteristics, and roles

In ecosystem settings, complementors take different shapes depending on the cited sources, which leads to inconsistencies across various definitions of complementors in the ecosystem literature. The concept of complementors has also overlapped with intersecting terms such as complements and complementary assets. This blending makes their distinction difficult to grasp and explain, reinforcing the findings from Sect. 4.2. As shown in Table 3, some researchers quote Brandenburger and Nalebuff's (1996) definition of complementors, focused on enhancing value (Kapoor 2013; Kapoor and Lee 2013; Gawer and Cusumano 2014; Adner 2017; Rietveld and Eggers 2018), while others refer to Teece's (1986, 2018) work on complementary assets, which are provided by complementors (Helfat and Raubitschek 2018). Lastly, in the platform ecosystem context, complementor- or platform-related studies are cited to define complementors.

Complementors are generally perceived as distinct downstream actors (Adner and Kapoor 2010) known for providing “*complementary products and services that contribute towards the focal offer's value creation*” (Kapoor 2018, p. 7).



**Table 3** Definitions of complementors in different types of ecosystems; according to the cited source. The emphasis of each definition appears in *Italics*

Definition	Source	Cited by	Synonyms	Ecosystem
Developers/producers of complementary products or services, whose output <i>enhances the customer value</i> of another product if they are consumed together (i.e., higher sales of one lead to higher sales of another)	Value net (firm, competitors, suppliers, customers, complements) (Brandenburger and Nalebuff 1996). In this context, complementors' relationships are often argued to be cooperative	(Kapoor 2013; Kapoor and Lee 2013; Gawer and Cusumano 2014; Adner 2017; Helfat and Raubitschek 2018; Rietveld and Eggers 2018)	<i>Complement providers</i> (Cennamo and Santaló 2019)	Innovation ecosystem, business ecosystem platform ecosystem
Complementary assets providers that have significant <i>value capture capability</i> (also encapsulates other kinds of firms besides complementors, e.g., technology providers)	Complementary assets, Profiting From Innovation (PFI) framework (Teece 1986, 2006, 2018)	(Helfat and Raubitschek 2018; Teece 2018)	Sometimes referred to as <i>complementors, complementary products providers</i> connecting to the above situation (Helfat and Raubitschek 2018)	Platform ecosystem
<i>Autonomous</i> /third-party providers/developers/producers of complementary products/components/goods/services	Platform-related studies (Cusumano and Gawer 2002, Boudreau 2012, Ceccagnoli et al. 2012, Zhu and Iansiti 2012, Gawer 2014, Gawer and Cusumano 2014, Boudreau and Jeppesen 2015, Rietveld and Eggers 2018) or complementor-focused studies (Yoffie and Kwak 2006)	(Boudreau 2010; Cennamo et al. 2013; Cennamo and Santaló 2013, 2019, Wareham et al. 2014, Benlian et al. 2015, Cennamo 2018, Nambisan et al. 2018, Ozalp et al. 2018, Rietveld and Eggers 2018)	<i>external innovators</i> (Cennamo 2018), <i>platform follower</i> (Nambisan et al. 2018)	Platform ecosystem
" <i>value-creation partners</i> " (Wen and Zhu 2019, p. 1337)	Complementor-related studies (Kapoor 2013)	(Wen and Zhu 2019)		Platform ecosystem

They can be viewed as part of the economic game for value capture from a game theory perspective (Brandenburger and Nalebuff 1996) or as an extension of the supply chain within the innovation ecosystem literature (Adner 2017). In business ecosystem literature, complementors may be regarded as “*neither buyers nor suppliers*” (Kapoor 2013, p. 5). However, certain expressions, such as “*firms providing complementary components*” (Hannah and Eisenhardt 2018), may erroneously bring complementors closer to the component supplier category.

Besides the common definitions of complementors from business and innovation ecosystems, the platform research stream offers a greater variety. In platform ecosystems, complementors are seen as “*key sources of distinct valuable resources*” (Cenamor et al. 2013, p. 413) or innovation (Boudreau 2012). Despite their importance, complementors are sometimes associated unfairly with consumers and treated as such, due to their periphery (Wareham et al. 2014) or downstream location in the value chain (Adner and Kapoor 2010). Additionally, in platform studies, complementors are often defined as suppliers of complementary products and/or services (West and Wood 2013; Thomas et al. 2014; Benlian et al. 2015; Boudreau and Jeppesen 2015; Kang and Downing 2015), or even “*supply-side users*” (Benlian et al. 2015). Another pattern specifically linked to digital platform context refers to complementors as software providers (Boudreau 2012) or app developers (Benlian et al. 2015; De Reuver et al. 2018; Eckhardt et al. 2018; Kapoor 2018; Zhu and Iansiti 2012).

Despite the diverse definitions, complementors exhibit several key characteristics. One common feature is their *autonomy*, which is particularly emphasized in platform ecosystem studies (Boudreau 2012; Ceccagnoli et al. 2012; Cenamor et al. 2013; West and Wood 2013; Thomas et al. 2014; Wareham et al. 2014; Benlian et al. 2015; Boudreau and Jeppesen 2015; Cennamo 2018; De Reuver et al. 2018). Complementors may not have formal partnerships or signed agreements with other ecosystem actors. Moreover, they may not share the same supply chains as other ecosystem members (Gawer and Cusumano 2014). Hence, the focal firm usually has no direct control over complementors or their products and services (Cennamo and Santaló 2019). However, in platforms, complementors rely on the platform technology to develop, supply, and promote their complements to users. In this way, complementors earn legitimacy and gain access to platform resources. However, this reliance implies complying with rules imposed by the platform owner, making complementors “*platform followers*” (Nambisan et al. 2018, p. 360).

Stemming from their autonomy, another feature of complementors is their *adaptability*. This characteristic allows complementors to originate from different markets (Gawer 2014), be highly responsive to changes in the focal product (Kapoor and Agarwal 2017), market, and customer demand. These adjustments would be otherwise more difficult for the focal firms to implement (Wareham et al. 2014).

*Heterogeneity* is another heavily stated characteristic of complementors in ecosystems. A variety of complementors is desired in any type of ecosystem because heterogeneous complementors deliver a wide variety of innovative complements that enhance the focal product’s value. Platform studies often mention the variety

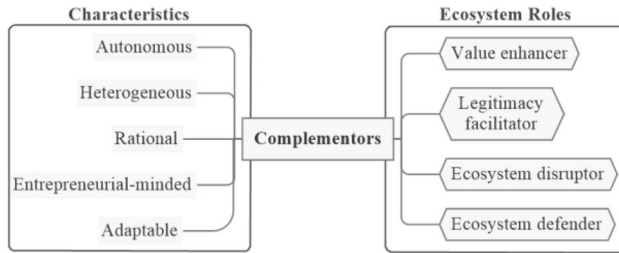


Fig. 9 Complementors' characteristics and their roles in ecosystems

characteristic, which together with a large number, can generate indirect network effects (Boudreau 2012; Scholten and Scholten 2012; Boudreau and Jeppesen 2015; Cennamo 2018; Cennamo and Santaló 2019).

Complementors are also considered to be *rational* and *entrepreneurial-minded* (Boudreau 2012; Cennamo 2018; Cennamo and Santaló 2019). They pursue their own interests of maintaining a competitive portfolio, acquiring and protecting knowledge, and gaining experience. Meanwhile, they deliver innovative solutions that meet customer needs at the speed required by the market (Boudreau and Jeppesen 2015; Cennamo and Santaló 2019). Figure 9 presents the characteristics and roles of complementors.

In line with the aforementioned characteristics, complementors' roles in ecosystems are multifaceted. First, complementors play an indispensable *value enhancement role* in materializing the core value proposition and unlocking its full-value potential (Kapoor and Agarwal 2017; Kapoor 2018). Through network effects, complementors can meet numerous and various customer needs, generating strong competitive advantages for the entire ecosystem and contributing to its survival, development, and progress (Boudreau 2010; Williamson and de Meyer 2012; Wareham et al. 2014; Adner and Kapoor 2016; Kapoor and Agarwal 2017; Rietveld and Eggers 2018; Teece 2018; Cennamo and Santaló 2019). Complementors' value creation also impacts the performance and success of the focal firm (Kapoor and Agarwal 2017). This reliance on complementors has been increasingly emphasized in business ecosystems (Kapoor 2013; Tsujimoto et al. 2018) and platform ecosystems (Eckhardt et al. 2018), as complementors determine the shift "*from product to network value*" (Li 2009, p. 380).

Secondly, complementors were found to also act as *legitimacy facilitators* in platform ecosystem studies. Whenever a platform releases a new technological generation, complementors can contribute to achieving legitimacy of the upgraded platform (Cennamo 2018). Thus, complementors are a critical source of ecosystem legitimacy.

Thirdly, complementors may act as *ecosystem disruptors*, exhibiting challenges and threats to ecosystem incumbents. During intergenerational transitions in technological paradigms, complementors could be crucial reasons for disruption in ecosystems (Ozalp et al. 2018).

A fourth role of complementors is *ecosystem defender*. They have the potential to obstruct others from entering the ecosystem by increasing the entry barriers and intensifying competition (Ozalp et al. 2018). However, in platform ecosystems, a high number of complementors also increases the demand and number of users through network effects and diversity of complements offered (Rietveld and Eggers 2018).

## 5.2 Complementors' interactions: participation determinants, challenges, and strategies

*Interactions with focal firms* yield several benefits, primarily deriving from the roles of complementors. However, the platform literature presents a more extensive list of benefits, e.g., enhancing commitment and value co-creation through knowledge and resource sharing (Nambisan et al. 2018), increasing the attractiveness of the platform (Boudreau 2012; Benlian et al. 2015), and showing confidence in the future of the respective platform (Ceccagnoli et al. 2012; Cenamor et al. 2013). This confidence transmits to potential users (Adner and Kapoor 2010; Cenamor et al. 2013).

The benefits of complementors' participation in ecosystems rest on the intensity of their involvement, influenced by various *determinants* (See: Table 4). In business ecosystems, the low appropriability risk (Kapoor 2013), compatibility consensus, and complementors' willingness to invest (Kapoor and Lee 2013) play crucial roles. Platform ecosystem studies provide further insights into the determinants of complementors' participation, e.g., platform-related factors like the size of the installed base (Cenamor et al. 2013; Cennamo 2018; Cennamo and Santaló, 2013; Kapoor 2018), governance mechanisms (Boudreau and Jeppesen 2015; Karhu et al. 2018), high purchase propensity (West and Wood 2013), the number of incentives (Benlian et al. 2015; Eckhardt et al. 2018), adequate share of value capture (West and Wood 2013; Cennamo 2018; Eckhardt et al. 2018), degree of platform openness (Benlian et al. 2015; Karhu et al. 2018), and extent of complementarity (Kapoor 2013). The complexity of complementors' relationships requires alignment of interests (Benlian et al. 2015), capabilities, and activities among the involved ecosystem members (Helfat and Raubitschek 2018). In addition, user behavior (Rietveld and Eggers 2018), time, and resources (Boudreau and Jeppesen 2015; Eckhardt et al. 2018) are strong determinants that complementors consider when participating in an ecosystem.

Two of the ecosystem features or governing forces that impact and shape complementors' interactions are interdependence and cooperation. *Interdependence* is the glue between members, the causal relationship between any two ecosystem actors that are affected by any change in one or the other (Jacobides et al. 2018). Business ecosystem studies suggest that the interdependence with complementors differs from that with suppliers. The distinction lies in the position of actors along the value chain (Kapoor 2018). Due to interdependence, balancing complementors' individual interests with the collective goals of the business ecosystem is challenging for complementors (Wareham et al. 2014).

**Table 4** Complementors' interactions, participation determinants, challenges, and strategies in ecosystems

	Business ecosystem	Innovation ecosystem	Platform ecosystem
Interactions with focal firm(s)	Value creation, enhance the performance of the focal product, boost sales, attract users (Kapoor 2013) <i>Potential for research exploration</i>	Enhance the performance of the focal product, boost sales, attract users (Kapoor 2013), transmit confidence to potential customers (Adner and Kapoor 2010)	Enhance commitment, stimulate value creation, knowledge and resource sharing, cost synergies (Nambisan et al. 2018), show their confidence in the future of the platform, which transmits to potential users (Ceccagnoli et al. 2012; Cennamo et al. 2013), more likely to timely react (Eckhardt et al. 2018), create comparative advantage through specialization and diversity (Boudreau 2012), increase platform attractiveness (Benlian et al. 2015)
Participation determinants	Low appropriability risk (Kapoor 2013), willingness to invest, compatibility consensus (Kapoor and Lee 2013) <i>Potential for research exploration</i>	<i>Potential for research exploration</i>	Ecosystem's maturity, generativity, benefits (Cennamo and Santaló, 2019), including financial gain (Boudreau and Jeppesen 2015, Eckhardt et al. 2018), number of incentives (Benlian et al. 2015), recognition (Eckhardt et al. 2018), platform openness (Benlian et al. 2015; Cennamo 2018; Karhu et al. 2018), governance mechanisms (Boudreau and Jeppesen 2015; Karhu et al. 2018), size of installed base (Cennamo et al. 2013; Cennamo 2018; Cennamo and Santaló, 2013), access to information (Eckhardt et al. 2018), high purchase propensity (West and Wood 2013), User behaviour (Rietveld and Eggers 2018), Complementors' capabilities (Boudreau 2010; Wareham et al. 2014) and the implied alignment of capabilities and activities (Helfat and Raubitschek 2018), risk preferences (Cennamo and Santaló 2019), individual perceptions and intentions (Benlian et al. 2015), willingness to invest, compatibility consensus (Ceccagnoli et al. 2012), Time and resources (Boudreau and Jeppesen 2015; Eckhardt et al. 2018)

Table 4 (continued)

	Business ecosystem	Innovation ecosystem	Platform ecosystem
Challenges	<p>For focal firm: coordination/management challenges (Jacobides et al. 2018; Kapoor 2018), possibility of conflict due to value appropriation and the risk/opportunity of entering each other's market space (Kapoor 2013)</p> <p>For complementors: balancing their own interest with the ecosystem's (Wareham et al. 2014), risk of focal firm's entry into complementary market (Kapoor 2013)</p>	<p>For focal firm: delayed delivery of complements, technological incompatibility, slow adoption, low performance (Adner and Kapoor 2010, 2016, Kapoor 2018), coordination challenges (Jacobides et al. 2018), (significant) value and profits strained away from the focal firm (Tece 2018), complement challenges and potential bottlenecks in value creation (Adner and Kapoor 2010)</p> <p>For complementors: <i>Potential for research exploration</i></p>	<p>For platform owner: balancing openness vs. control (Cennamo 2018), (almost) no control on third-party complement supply (West and Wood 2013), platform forking (Karhu et al. 2018), delayed delivery of complements (Cenamor et al. 2013), quality of complements, coordination issues (Cennamo 2018, Jacobides et al. 2018; Scholten and Scholten 2012), straining away (significant) value and profits from the focal firm (Tece 2018)</p> <p>For complementors: new learning processes, high development costs, compatibility adjustments (Cennamo 2018; Ozalp et al. 2018), platform owner's control over the profit/value capture allocation (West and Wood 2013) or eagerness to capture more value (Wen and Zhu 2019), increasing fees, restricted access to the platform, resources, user base or information (Foerderer et al. 2018, Nambisan et al. 2018, Rietveld and Eggers 2018, Wareham et al. 2014, Zhu and Liu 2018), risk of platform owner entering the complementary market, i.e., becoming direct competitors (Cennamo 2018, Foerderer et al. 2018)</p>

Table 4 (continued)

	Business ecosystem	Innovation ecosystem	Platform ecosystem
Strategies	Multithoming (Kapoor 2018) <i>Potential for research exploration</i>	Establish formal relationships with the focal firms to ensure consensus for compatibility and conflict resolution (Kapoor and Lee 2013) <i>Potential for research exploration</i>	Establish formal relationships with the focal firms to ensure consensus for compatibility and conflict resolution (Ceccagnoli et al. 2012), Risk mitigation strategies, e.g., continuously invest in the RandD and protection mechanisms, avoid providing popular complements and, consequently, unwanted competition risk from platform owners, obstruct the information channel through price increases to seem less popular, lock in suppliers, build custom-made proprietary complements, etc. (Foerderer et al. 2018; Zhu and Liu 2018), multithoming (Cennamo et al. 2018; Cennamo and Santaló 2019) To platform owner market entry: (a) Diminish development and innovation efforts (a common reaction), (b) Continue to innovate the product in question to enhance the potential of being acquired by the platform owner or lock-in as many customers to ensure future profits and market position, (c) Focus on short-term profits by changing their pricing strategy considering the degree of vulnerability and, thus, diminishing their chance of being acquired, (d) Increase or speed up their innovation activities (i.e., racing effect), (e) Multithoming, (f) Exit the ecosystem, etc. (Foerderer et al. 2018, Li and Agarwal (2017), Rietveld and Eggers 2018; Wen and Zhu 2019)
Interactions among complementors	<i>Potential for research exploration</i>	<i>Potential for research exploration</i>	Simulate stronger network effects (Boudreau and Jeppesen 2015), wider variety and quality of complements (Boudreau 2012; Cennamo 2018; Cennamo and Santaló, 2013)

Table 4 (continued)

	Business ecosystem	Innovation ecosystem	Platform ecosystem
Participation determinants	Knowledge sharing, the possibility to combine resources and capabilities (Kapoor 2013)	<i>Potential for research exploration</i>	Tackling the platform growth, knowledge sharing and peer learning, forming an identity (Boudreau and Jeppesen 2015), low ecosystem entry barriers for complementors (Wareham et al. 2014), Platform owner's power over complementors' survival and promotion (Rietveld et al. 2019), the share of value captured by the platform owner (Wen and Zhu 2019), entry (or even intent) of platform owner in complementary market (Boudreau 2010)
Challenges	<i>Potential for research exploration</i>	<i>Potential for research exploration</i>	Intense competition (Boudreau 2012, Cennamo 2018, Cennamo and Santaló 2013), overcrowding effects (Boudreau 2010, Gawer and Cusumano 2014, Ozalp et al. 2018, Wareham et al. 2014) <i>Potential for research exploration</i>
Strategies	<i>Potential for research exploration</i>	<i>Potential for research exploration</i>	<i>Potential for research exploration</i>



Another dynamic drive featured in the complementors' interactions with other ecosystem actors is *coopetition*, i.e., simultaneous cooperative value creation and competitive value capture. Complementors pursue the common goal of realizing the core value proposition, thereby increasing the business pie for all ecosystem actors. However, owing to their autonomy, complementors may exhibit competitive dynamics in capturing their share of value. Thus, complementors' relationships are characterized by the value creation-capture duality (Kapoor 2013). Their different degrees of cooperation and competition shape the ecosystem's structure and its governance system (Gawer 2014).

These two forces, interdependence and coopetition, generate various challenges for both focal firms and complementors. On the one hand, collaboration with complementors can strain away (significant) value and profits from the focal firm(s) (Teece 2018). Complementors also present coordination challenges for focal firms, which can take various forms, such as delays, incompatibility, slow adoption, low performance, and integration issues (Adner and Kapoor 2010, 2016; Kapoor 2018). These challenges may affect the reputation, success, and health of the ecosystem as a whole (Scholten and Scholten 2012). Without proper coordination, these complement challenges can lead to bottlenecks in realizing the ecosystem's value proposition (Adner and Kapoor 2010). On the other hand, complementors also face challenges due to an obvious power imbalance in their interactions with the focal firms. The most significant challenge is when the focal firm enters the complementary market space, turning them into direct competitors. This theme has received some research interest in business ecosystems (Kapoor 2013), but this coopetition scenario seems more common in platforms (Cennamo 2018; Foerderer et al. 2018). The generally unavoidable complementary market entry by the platform owner may be aimed at preventing complementors from becoming too powerful (competitors) (Wen and Zhu 2019). Under the threat of direct competition from the platform owner, complementors' strategies vary according to the number and popularity of the affected products from their portfolio.

To deal with the aforementioned challenges, complementors may resort to establishing formal relationships with the focal firms instead of loosely coupled interactions (Ceccagnoli et al. 2012; Kapoor and Lee 2013) or engaging in multihoming, a complex strategy more common in platforms that may result in access to more market opportunities and a distributed risk (Cennamo et al. 2018; Kapoor 2018; Cennamo and Santaló 2019). However, multihoming may dilute the platform's value proposition, generate technical integration issues, and affect the quality of multihoming complements (Cennamo et al. 2018). Further research on multihoming complementors in other ecosystem types will render a more profound understanding of this strategy.

In addition to the interactions between complementors and focal firms, interactions among complementors have also received some attention. Collaboration among complementors was found to be more prone to creating positive network effects in platform studies (Boudreau and Jeppesen 2015). The motivations behind this action may be various, such as tackling platform growth through knowledge sharing, forming an identity by affiliation, or combining resources and capabilities (Kapoor 2013;

Boudreau and Jeppesen 2015). However, complementors inevitably compete for the same user base (Boudreau and Jeppesen 2015) or profit from the jointly developed innovations (Rietveld et al. 2019; Zhu and Liu 2018). These competitive dynamics can shift and intensify for various reasons, such as the platform owner's power over complementors' survival and promotion (Rietveld et al. 2019), the share of value captured by the platform owner (Wen and Zhu 2019), entry (or even intent) of platform owner in complementary market, attaining the position of complementor also (Boudreau 2010), numerous complementors and, subsequently, overcrowding effects (Boudreau 2010; Gawer and Cusumano 2014; Wareham et al. 2014; Ozalp et al. 2018), and low ecosystem entry barriers for complementors (Wareham et al. 2014). These actions not only affect participating complementors, but also demotivate prospective complementors from entering the ecosystem (Gawer and Cusumano 2014; Wareham et al. 2014). The strategies complementors employ in their interactions with other complementors represent a wide venue for future research in any type of ecosystem.

### 5.3 Complements and complementary assets

In ecosystem literature, complementors are closely related to complements and complementary assets. Although these concepts are distinct, their overlaps can cause confusion (Adner 2017). *Complements* are defined as additional innovations that enhance the value of the focal product, allowing it to reach its full potential, as its individual value would otherwise be lower (Adner and Kapoor 2010; Gawer and Cusumano 2014; Eckhardt et al. 2018; Karhu et al. 2018; Ozalp et al. 2018). Complements are not only offered by complementors; often times focal firms also own and deliver complements (Cenamor et al. 2013). Complementors' output is identified as *downstream* or *third-party complements*, distinguishing them from upstream complements or components in terms of location (Adner and Kapoor 2010; West and Wood 2013; Thomas et al. 2014; De Reuver et al. 2018; Kapoor 2018; Parker and Van Alstyne 2018). To minimize confusion, complements delivered by the platform owner are seldom referred to as first-party complements (Cennamo 2018).

In ecosystem studies, complements are referred to by various names, e.g., *complementary products/services/goods/technologies* (Boudreau and Jeppesen 2015; Cenamor et al. 2013; Cennamo 2018; Eckhardt et al. 2018; Jacobides et al. 2018; Kapoor 2018; Li 2009; Parker and Van Alstyne 2018; Tsujimoto et al. 2018), *complementary innovations* (Gawer and Cusumano 2014; Benlian et al. 2015; Cennamo 2018; Foerderer et al. 2018), *complementary components* (Hannah and Eisenhardt 2018), or, more exclusively to platforms, *complementary modules* or *applications* (Benlian et al. 2015; Zhu and Iansiti 2012), *extensions* (Cennamo et al. 2018), *peripherals* or *peripheral elements* (Boudreau 2010; Cenamor et al. 2013), *edge technologies* (Boudreau 2010), *modules* or *(complementary) third-party modules* (Boudreau 2010; De Reuver et al. 2018). The greater variety of terminologies for platform complements may arise from

the common integration of third-party complements by platform owners (West and Wood 2013).

The diversity, quality, and generativity level of complements contribute to the success of focal firms (Adner 2006), create indirect network effects, and impact the value of the entire ecosystem (Jacobides et al. 2018; Rietveld et al. 2019). However, complements also increase the interdependence and complexity of the ecosystem (Cennamo et al. 2018; Zhang et al. 2022). In platform ecosystems, the number and variety of complements are typically larger and spur innovation (Cenamor et al. 2013; Kang and Downing 2015; Cennamo et al. 2018; Eckhardt et al. 2018; Cennamo and Santaló 2019). Complement quality directly correlates with user satisfaction (Cennamo and Santaló 2019), but the impact of complements varies depending on each complement's popularity (Cenamor et al. 2013).

Considering the blurred notional delimitations among the relevant keywords as noticed by Adner (2017), *complementary assets* have also emerged as a distinct theme. While connected to Teece's framework (1986), which considers a firm's complementary assets (i.e., capabilities and resources) in its strategic decisions for capturing value, complementary assets are also relevant in the context of ecosystem's value creation (Adner and Kapoor 2010; Teece 2018). The availability of complementary assets in ecosystems offers various advantages, including acting as an entry barrier (Ceccagnoli et al. 2012) and contributing to value creation (Thomas et al. 2014). The development or modification of complementary assets must occur before product commercialization to allow full potential extraction by customers (Adner and Kapoor 2010). Nevertheless, ownership of complementary assets or the capability to develop and/or manage them creates a competitive advantage that influences the division of profits (Teece 2018).

Complementary assets are not only internal to focal firms but are also used as a synonym for downstream complements provided by third-party complementors (Li 2009; Thomas et al. 2014). Complementary assets can be categorized as vertical and lateral or, more commonly, depending on the type of the complementarity involved (as complements categorization) (Teece 2018).

## 5.4 Complementarity

*“Complementarity lies at the core of ecosystems”* (Teece 2018). As a key feature and building block for the ecosystem theory, an understanding of the different natures of *complementarities* generated by complementors is needed. Although shedding some light on this concept is still considered a challenge (Jacobides et al. 2018; Kapoor 2018; Teece 2018).

In ecosystem research, complementarity generally associates with the economic synergy created by a mix of at least two assets that generate a higher value or utility under a combined solution (Cenamor et al. 2013; Kapoor 2018). The value-added potential of complementarities is contingent on the effectiveness of relationships (Adner 2006), interdependence (Kapoor 2013; Cennamo 2018), and alignment of value co-creating interactions within ecosystems (Thomas et al. 2014; Jacobides

et al. 2018). Complementarities have the power to enhance value and shape ecosystem development (Teece 2018), determine its competitiveness, and increase its resilience (Thomas et al. 2014). Analyzing the nature of complementarities contributes to understanding the value creation-capture duality within, and also across, ecosystems (Jacobides et al. 2018).

Complementarities in ecosystems come in various types, such as unidirectional or bidirectional, generic or specialized/specific (Jacobides et al. 2018; Kapoor 2018); unique or supermodular/Edgeworth (Jacobides et al. 2018). However, complementarities strictly generated by complementors are multilateral, involving a to-and-fro influencing relation on various parties' value, and nongeneric, assuming (some) customization and coordination of operations and other aspects (Jacobides et al. 2018). Nongeneric complementarities and their management represent the essence, dynamics, and distinctive features of ecosystems (Jacobides et al. 2018). Downstream complementarities, whether unique or the more prevalent supermodular/Edgeworth type, render the degree of interest that participants have in ecosystem health (Jacobides et al. 2018).

Furthermore, complementarities specifically connect to *indirect network effects*, as network effects reinforce the impact generated by complementarities among ecosystem actors (Gawer 2014). It is worth noting that supermodularity in consumption can result in both direct and indirect network effects (Jacobides et al. 2018). However, the value-enhancing impact of complement availability, number, and variety on the focal proposition may not be unlimited. In some ecosystems, a large number of complementors may deter others from being willing to join due to saturation (Gawer and Cusumano 2014; Cennamo and Santaló 2019). Further research is needed to determine when indirect network effects cease to be beneficial for the ecosystem.

## 5.5 Key findings of content analysis

In our content analysis, we first uncovered an inconsistency across various definitions of complementors within ecosystems, which can lead to confusion in understanding their role(s). To clarify this concept, we identified several key characteristics of complementors, i.e., autonomy (although in platforms, complementors rely on the provided infrastructure to develop and sell their complements (Nambisan et al. 2018)), adaptability, heterogeneity, rationality, and entrepreneurial mindset. Building upon these identified characteristics, we unveiled complementors' roles in ecosystems, i.e., value enhancement, legitimacy facilitation, ecosystem disruption, and ecosystem defense.

We then mapped out complementors' interactions, participation determinants, challenges, and strategies in relation to the interacting party, i.e., focal firms and other complementors. While platform studies offer valuable insights into these aspects, there remains a need for comprehensive research attention to understand the dynamics of complementor interactions across various types of ecosystems.

Finally, we addressed the conceptual overlaps with intersecting terms, i.e., complements, complementary assets, and complementarity. By showcasing their distinctions, we clarified their unique roles and contributions within ecosystems.

## 6 Discussion and future research

To clarify our understanding of complementors in an ecosystem setting, we conducted a systematic literature review using two methods. The bibliometric and content analyses revealed insights at different levels. The systematic approach ensured objectivity and reliability of findings. However, this review is not exempt from limitations. First, the inclusion of the keyword “*ecosystem*” in the search string might have omitted some platform ecosystem studies and more recent articles. Second, the number of articles in the content analysis is limited. To overcome these limitations, we will widen our discussion perspective by including relevant articles outside our dataset, and pave future research avenues for the literature stream on complementors in ecosystems.

### 6.1 Complementors as ecosystem actors

With increasing attention from the ecosystem research stream, complementors are recognized as key actors in realizing the core value proposition. Their contribution to the ecosystem’s core value proposition unlocks greater potential for the customers and expands the pie for all ecosystem actors (Kapoor and Agarwal 2017). Additionally, complementors play a pivotal role in determining the survival and development of the ecosystem (Brandenburger and Nalebuff 1996; Iansiti and Levien 2004; Kapoor and Lee 2013). Consequently, academic interest in studying complementors as ecosystem actors has grown, particularly since 2018, with a focus on platform ecosystems. However, this topic is tackled disproportionately across different types of ecosystems, calling for more research on complementors in business, innovation, and entrepreneurial ecosystems.

Defining *complementors* in ecosystems poses challenges due to different fundaments being used. This practice stretches the concept in multiple directions, causing a dilution of its perceived usefulness. Although first introduced by Brandenburger and Nalebuff (1996), complementors take on various forms in different kinds of ecosystems, depending on the cited source and emphasized features, i.e., value enhancement nature (Brandenburger and Nalebuff 1996; Kapoor 2013), value capture capability (Teece 2018), and autonomy (Boudreau 2012; Boudreau and Jeppesen 2015; Ceccagnoli et al. 2012; Cusumano and Gawer 2002; Gawer and Cusumano 2014; Yoffie and Kwak 2006; Zhu and Iansiti 2012). Generally, complementors are actors whose output enhances the value of a core product (or service) when consumed together. This integration is (normally) performed by the customer. While this statement holds true in platform ecosystems, where users typically choose the complements, other ecosystems, like innovations ecosystems (without platform), may require dual-party coordination between focal firms and complementors before commercialization. In such cases, the responsibility to unlock the full-value potential lies with both parties. For instance, Adner and Kapoor’s (2010) example with Airbus A380 and airports demonstrates that (sometimes) integration must be performed before making it available to customers. Thus, adjustments to the definition of complementors may be necessary to accommodate different ecosystem types.

Considering complementors' characteristics, further reflections on their autonomy are warranted. As the most stated characteristic and a reason for the complexity of their cooperative relationships, complementors' autonomy is expected to be maintained in all ecosystems. However, their autonomy is often associated with coordination challenges and collaboration risks. Complementors may be encouraged to innovate and develop in ecosystems that ensure or augment their autonomy (Kapoor and Agarwal 2017). However, complementors' autonomy may affect their responsiveness, unless proper and targeted coordination is involved in their interactions with other ecosystem actors (Brusoni and Prencipe 2013; Kapoor 2013). Despite being autonomous, complementors are subject to certain rules or standards when participating in ecosystems (Scholten and Scholten 2012; Jacobides et al. 2018). In platform ecosystems, they heavily rely on the platform's technology to develop and commercialize their innovations, as well as to connect with users and perform transactions (Ceccagnoli et al. 2012; West and Wood 2013; Thomas et al. 2014; Nambisan et al. 2018; Parker and Van Alstyne 2018; Agarwal et al. 2023). However, these restrictions and technological dependence may hinder complementors' autonomy.

Based on their characteristics, several roles of complementors in ecosystems have been identified, including value enhancer (Kapoor and Agarwal 2017; Kapoor 2018), legitimacy facilitator (Cennamo 2018; McIntyre et al. 2020; Tauscher and Rothe 2021), ecosystem disruptor (Ozalp et al. 2018; Adner 2021; Adner and Lieberman 2021), and ecosystem defender (ibid.). While complementor's roles have been emphasized over the past three decades, particularly in business ecosystem studies (Tsujiimoto et al. 2018), platform ecosystem publications investigating complementors have become more numerous. This may be due to the agglomeration of complementors in platforms, their number, facile identification, or their absolute necessary presence on the platform for ecosystem success and dominance (Cenamor et al. 2013; Cennamo 2018; Jacobides et al. 2018; Saadatmand et al. 2019). Moreover, although generally seen as platform participants who require management by the platform owner to maximize their added value, dominant complementors can even influence their management through network effects, extending their roles beyond value enhancement (Agarwal et al. 2023). Furthermore, depending on the degree of platform openness, complementors can even change the platform architecture (van der Geest and van Angeren 2023), revealing their dynamic and multifaceted impact on platform ecosystems. Additional research on complementors may identify more roles across different ecosystem types.

The challenge of navigating complementors' interactions is also a highlight in this review. Initially, emphasizing their collaborative nature, the thematic evolution showed that the complementors theme emerged in 2019 stemming from network effects, competition, and innovation. This proves the competitive dimension of complementors' interactions. Understanding complementors' contribution in ecosystems as not solely a derivative of value creation but also involving dynamics of value capture is essential (Adner and Kapoor 2010). Although competition dynamics are undeniably present and linked to complementors, their investigation in interactions with focal firms but also among complementors remains underexplored in ecosystem research (Gawer 2014). Further studies on the variations and intensity of value creation opportunities and value capture risks among complementors and between

the focal firms and complementors may uncover cooperation-competition patterns (Kapoor 2013; Gawer 2014).

Complementors and focal firms can enter each other's product space (Kapoor 2013). While some studies have examined the platform owner's entry into complementary markets (Gawer and Cusumano 2002; Gawer and Henderson 2007), research on their entry patterns and complementors' responses remains limited (Ceccagnoli et al. 2012; Zhu and Liu 2018; Kang and Suarez 2023). Complementors may also engage in various forms of exploitation, e.g., forking, hacking, infringement, multihoming, to profit from economies of scale (Karhu et al. 2018; Cennamo and Santaló 2019; Tian et al. 2022; Chung et al. 2023). Restricting complementors' access (to a single platform) can improve the complement quality through exclusivity and focused investment (Casadesus-Masanell and Halaburda 2014; Chu and Wu 2023). Nevertheless, such restrictions may reduce the quantity of complements due to platform exit or hinder complementors' willingness to engage with other platforms (Eisenmann et al. 2009; Boudreau 2010; Chung et al. 2023). Moreover, the performance of exclusive complementors in the video game platform context has been found to be weaker (Castro and Sant'Anna 2023). Further investigation on the degree of ecosystem openness and the impact of complementors' exploitative strategies could offer valuable insights into their innovativeness and behaviors in ecosystems.

## 6.2 Complementors, complements, complementary assets, and complementarity: inconsistencies and propositions

*Complementors* maintain their importance as a defining element in ecosystem theory, but the findings indicate a slowdown in the use of interrelated concepts, i.e., *complements*, *complementary assets*, and *complementarity*. Despite conceptual overlaps, their disconnectedness stresses the need for clarifying research and a more careful application of these concepts.

Although with a different origin, *complementarity* not only serves as a building block of ecosystems but also plays a critical role in the discussion about complementors. This is because high complementarities render significant value to customers and, consequently, to ecosystems (Adner 2006; Xu et al. 2010; Teece 2018). However, how to achieve these complementarities in ecosystems is yet to be understood (Jacobides et al. 2018). It is essential to note that complementors in ecosystems are not the actors involved in any (type of) complementarity. Instead, they are strictly linked to multilateral, non-generic complementarities, which are considered an essential and distinctive feature of ecosystems.

Regarding *complementors* in ecosystems, we propose a refined definition that considers the identified characteristics. Complementors in ecosystems are generally perceived as:

*Autonomous, entrepreneurial-minded, rational, and highly adaptable downstream actors whose complementary innovations, i.e., (downstream)*

*complements, augment the value of the focal proposition when consumed together by the user.*

Complementors maintain their significance across different types of ecosystems, but their *autonomy* characteristic may be affected in platform ecosystems. In this setting, complementors base the development of their business and products on the platform's architecture and resources. In this case, complementors are sometimes even called "*followers*" (Nambisan et al. 2018, p. 360). Hence, their autonomy and interdependence with the focal firm or (platform) ecosystem's structure and resources may be inversely proportional. Possibly, the degree of complementor dependence on the platform ecosystem in which they participate is higher than in other types of ecosystems.

Special attention should also be given to the concepts of complementarities and complementary assets, as they are sometimes used interchangeably. Moreover, since complementary assets are found along the entire value chain, they may not necessarily or strictly refer to complementors as downstream actors. Dividing complementary assets according to their origin in the value chain, i.e., upstream and downstream complementary assets, can help eliminate confusion. Thus, when exclusively referring to complementors' output, an option would be to use the term *downstream complementary assets*.

Although *complements*, *complementary assets* and *complementarity* share a common word stem and intersecting conceptual features, they may not solely concern complementors. Therefore, distinctions, clarifications, and cautious use of these concepts in ecosystem studies are required. For instance, even though *complements* are a broad term that generally encompasses the products, activities, or services resulted from complementarities, in an ecosystem setting using (*downstream*) *complements* as only referring to complementors' output would clear out the confusion. Other terminologies, like third-party innovation (Parker and Van Alstyne 2018), are vague and may refer to the output of all external actors. Although, "*third-party innovation*" excludes the innovation provided by the focal firms.

### 6.3 Gaps and future research avenues

Despite the remarkable development of literature on complementors and their role in ecosystems over the past two decades, this study has unveiled several research gaps. Further potential research venues in connection to the following gaps are also proposed in Table 5.

First, the disconnect among the concepts of *complementors*, *complementarity*, and *complementary assets* in ecosystem studies highlights the disproportionate attention and disparate development of these topics. Their conceptual distinctiveness and individual contribution to ecosystem research stream require further clarification.

Secondly, although complementors are recognized as key ecosystem actors, the existing literature is inconclusive and inconsistent regarding their definition, characteristics, and role(s) (McIntyre and Srinivasan 2017; Ozalp et al. 2018). Empirically



**Table 5** Potential research venues uncovered by the review

	Business ecosystem	Innovation ecosystem	Platform ecosystem
Conceptual distinctiveness	How to define and categorize complementors in ecosystem research? How do complementors along interrelated concepts, i.e., complements, complementary assets, complementarity individually contribute to the ecosystem literature?		
Roles and characteristics	What/where are the conceptual overlaps and distinctiveness? What other roles complementors hold in different ecosystem contexts? How complementors contribute to the sustainability of the ecosystem? What features complementors exhibit depending on the degree/nature of complementarity/complement integration locus/extent of interdependence? Do these aspects emerge into types of complementors?		
Interactions with focal firm(s)/other complementors	How to coordinate complementors? How do complementors manage their cooperative interactions with other ecosystem actors? Are the interaction and collaboration patterns of complementors contingent on the type of ecosystem or its maturity? How do the variety and quality of complements influence the ecosystem's value and competitive dynamics? How different governance modes/degree of interdependence impact the interactions with complementors and their added value? How are the interdependencies between complementors and ecosystem/focal firm(s) properly and strategically coordinated?		What coordination processes and mechanisms are most efficient for complementors?
Participation determinants	What determines complementors to interact with the focal firm(s)? What are the determinants for complementors to interact with other complementors? Are these determinants/motivators different from those for the interactions with the focal firm(s)?		
Impact and challenges	<i>For focal firm:</i> What other risks and challenges complementors pose in different kinds of ecosystems? How complementors' presence and contribution impact the evolution and development of the ecosystem? How can focal firm(s) successfully manage/coordinate with complementors to avoid complement challenges? <i>For complementors:</i> What other risks and challenges complementors face in different kinds of ecosystems? Are these risks higher or more intense in certain types of ecosystems, considering that, for instance, in platform ecosystems the focal firm can access (and even store) data about the complementors' business on the platform? Do complementors in innovation and business ecosystems face this issue at the same intensity?	<i>For platform owner:</i> How the number and uniqueness of complementors influence value creation and competition? <i>For complementors:</i> How does the complementors' dependence on the platform resources (and possible rules and guidelines) for complement development impact their autonomy and strategic decisions?	

Table 5 (continued)

	Business ecosystem	Innovation ecosystem	Platform ecosystem
Strategies	<p>What are the needed capabilities for complementors to capture value in ecosystems? How could complementors better use their capabilities for value capture? Are these capabilities contingent to the type of ecosystem they participate in? What strategies complementors engage in business and innovation ecosystems? How do complementors respond to direct competition from the focal firm's entry into the complementary market?</p> <p>How do complementors engage in multihoming strategy in business and innovation ecosystems?</p> <p>What strategies complementors employ in their interactions with other complementors?</p> <p>How do complementors respond and solve complement challenges of the ecosystem?</p>	<p>What governance forms strikes the right balance between openness and control to foster complementary innovations?</p>	

studying the nuances and evolutions, if any, in complementors' behaviors and features across different (types of) ecosystems can facilitate a general and more in-depth understanding of complementors as ecosystem actors, as well as a clarification of their definition. Alternatively, we could consider defining complementors based on the type of ecosystem they participate in. Given this gap, the development of methods to identify and categorize complementors, as well as to evaluate or measure their performances, is deemed necessary. Such efforts will contribute to a more unified and refined understanding of complementors' characteristics and contribution within ecosystems.

Thirdly, considering the complexity of complementors' relationships, natures, and functions, more recognition and empirical evidence on their (coopetitive) interactions are needed, particularly in the contexts of innovation and business ecosystems. While research on complementors in platform ecosystem has grown (Liang et al. 2022), understanding their relationships and interactions in business or innovation ecosystems requires further investigation. In these settings, do complementors rely more on transactions and, consequently, traditional agreements? Regarding complementors' interactions with focal firms, the interdependence between these actors, particularly during the emergence of platform ecosystems, has been acknowledged. At this stage, the platform and complementors are co-dependent, but unwilling to invest until the other is populated enough, generating the chicken-and-egg problem (Hein et al. 2020). However, effective management of these interdependencies demands further research (Gawer and Henderson 2007; Kapoor and Lee 2013), particularly on how interdependencies between complementors and ecosystems are properly and strategically coordinated in business and innovation ecosystems. Additionally, the interplay between cooperation and competition among complementors represents a notable research gap with significant potential for future exploration in various ecosystem types. Investigating the circumstances under which complementors engage in collaboration despite the obvious competitive dynamics for value capture, the determinants of their participation in such interactions, and their assumed challenges, and strategies employed during collaboration remain intriguing avenues for ecosystem research. Embracing the inherent phenomenon of coopetition can help complementors on platforms like Amazon cope with paradoxical tensions (Yoo et al. 2022). Extending these investigations to other ecosystem types can provide valuable insights into complementors' perspectives and their management of coopetition in their complex interactions with diverse ecosystem actors.

Fourthly, concerning complementors' strategies, it is rather unclear what capabilities they need to capture value in ecosystems and how these capabilities can be more effectively utilized for this purpose (Helfat and Raubitschek 2018). Are these capabilities different depending on the kind of ecosystem? For example, sensing by platform complementors in the metaverse context (Zabel et al. 2023) highlights the need for understanding complementors' capabilities in ecosystems. Addressing this research direction can shed light on how complementors effectively balance collaborative efforts, enhance downstream innovation, and optimize their positions and roles within the ecosystem. Thus, conceptualizing different types of complement strategies may help understand how their number and uniqueness influence value creation and competition on ecosystems (McIntyre and Srinivasan 2017).

Fifthly, further research is required on the impact and challenges that complementors assume and pose. Are these risks higher or more intense in certain types of ecosystems, considering that, for instance, in platform ecosystems, the focal firm can access, and even store, data about the complementors' business on the platform? Do complementors in innovation and business ecosystems face this issue to the same degree? Therefore, competition and governance are venues worth exploring regarding complementors. Additionally, the connection between complement quality and variety, as well as their impact on the ecosystem's value, sustainability, and competitive dynamics (Cennamo 2018) also require further investigation.

Finally, a major gap in the extant ecosystem literature is the lack of studies from the complementors' perspective. Taking their vantage point may reveal a different side of the story. Given the interdependence and mutual influence between complementors and other ecosystem actors, more research may emerge on how complementors should strategize to adapt and survive in different types of ecosystems. Theory-building on complementors' strategies and interactions can enrich the ecosystem literature and strategic management scholarship.

#### 6.4 Practical implications

This systematic review highlights the pivotal role of complementors in realizing the ecosystem's core value proposition and sheds light on their alternative roles, which can positively or negatively influence the ecosystem success and development. Policymakers and managers seeking to stimulate ecosystem expansion should recognize the significance of complementors and promote collaboration with and among them. Preserving complementors' autonomy can stimulate innovation and responsiveness, while being mindful of their potential for competition and cooperation. Understanding complementors' roles, characteristics, participation determinants, interactions patterns, and challenges can inform strategies for fair competition, stimulating innovation, maximizing the benefit of the core proposition, and safeguarding the ecosystem.

### 7 Conclusion

This systematic review assists the consolidation of existing knowledge on complementors and facilitates the development of ecosystem research. To the best of our knowledge, this study represents a pioneering attempt to comprehend complementors based on the extant ecosystem literature. With increasing research interest in complementors, particularly since 2018, managers should take notice of them and address the diverse challenges they may pose or face. Proper identification and coordination of complements, ideally before commercialization to avoid adoption delays, are essential for the focal offering to reach its full-value potential. In addition to identifying and recognizing complementors' roles (Adner and Kapoor 2010; Boudreau 2010), unpacking their interactions and challenges reveals a more

profound understanding influencing the success of the core value proposition and ecosystem health (Iansiti and Levien 2004; Adner 2012). Paying attention to complementors' competitive dynamics warrants further investigation for the sake of proper coordination. Thus, more research on their strategies and the (coopetitive) challenges they pose is needed (Zhu 2019).

Lastly, the disproportionate focus on different types of ecosystems and research designs reflects the ongoing development of the ecosystem research stream. Empirical research dominates the literature on complementors in various ecosystems, primarily in platform ecosystems, possibly due to their high number and increased visibility, rendering their effortless identification in platform ecosystems. However, this imbalance limits generalizations regarding complementors. Therefore, complementors still require further clarification and research regarding their roles, interactions, and strategies in ecosystems, to manage and collaborate with them efficiently.

## Appendix 1: Types of complementarities

Type of complementarity	Other terminologies	Relevant researchers	Short explanation	Notes
Cournot complementarity	Input oligopoly complementarity	(Cournot 1838)	Two individually sold products by two monopolistic companies are consumed at the same time	In an innovation ecosystem setting, this type of complements may appear in the form of bottlenecks that are needed for the creation and commercialization of an innovation (Teece 2018)
Edgeworth complementarity	Pareto complementarity or Supermodular complementarity (as it is more commonly used/known nowadays)	(Edgeworth 1897, Milgrom and Roberts 1990, Jacobides et al. 2018, Teece 2018)	A higher utility resulted from the simultaneous consumption of two products (or services, assets, activities), than separated, individual consumption	The consumption of one product positively impacts the value and demand of the other. This complementarity can be found in consumption and production
Strong complementarity	Strict complementarity	(Hart and Moore 1990)	Two products that generate value only through joint use	The individual use of one of the two products would not generate any benefit

Type of complementarity	Other terminologies	Relevant researchers	Short explanation	Notes
Hicksian complementarity	Production complementarity	(Hicks 1970)	A price decrease in production factor triggers an increase in the quantity of its complements that are used in the production	Not fully relevant for innovation research because of its hypothesis of an existing link between the two factors. But its contribution lies in the idea that commercializing an innovation impacts the demand for its complements
Hirshleifer complementarity	Asset price complementarity	(Hirshleifer 1978)	The impact of an innovation on the asset prices of another	Financial equivalent of Hicksian complementarity. It aims at profiting from an innovation (Teece 1986, 2018)
Technological complementarity		(Teece 1986, 2006, 2018)	When an innovation needs new and/or re-engineered complementary technologies to reach its full-value potential	A type of technological complementarity is innovational complementarity (Teece 2018)
Innovational complementarity		(Teece 1986, 2018)	Downstream productivity boost generates by an improved technology meant for extended uses	It may be considered a type of technological complementarity (Teece 2018)
Generic vs. unique complementarity		(Teece 1986; Jacobides et al. 2018)	No involved coordination due to its generic feature vs required customization	Unique complementarity is generated from one-way relation (i.e., the first item requires another to function, though a third item can be used with a possibly lower efficiency; linked with transaction cost economics) or two-way relation (i.e., both items need each other; linked with the concept of co-specialization, resulting into co-specialized assets (Teece 1986) or technological complements (Teece 2018))

## Appendix 2: Overview of 44 articles selected for content analysis

References	Type of research	Research question/objective	Type of ecosystem	View on complementors and related concepts
Adner (2017)	Conceptual/theoretical	<i>A structuralist approach to conceptualizing the ecosystem construct</i> (p. 39)	Ecosystem	Conceptual blending of complements, complementors and complementary assets as are all seen as improvements towards the focal firm's product/service. Call for research on the management of complementors
Adner and Kapoor (2010)	Empirical qualitative	<i>How do the challenges faced by external innovators affect the focal firm's outcomes?</i> (p. 306)	Innovation ecosystem	Importance of complement challenges. Complements are integrated downstream by the customer with the focal product. Complement challenges negatively impact the expected benefits of the focal firm
Adner and Kapoor (2016)	Empirical mixed methods	<i>Why do some new technologies emerge and quickly supplant incumbent technologies while others take years or decades to take off?</i> (p. 625)	Innovation ecosystem	Complementors as ecosystem actors. Complements are their value-enhancing output that is integrated by the customer with the focal offering. Like components, complements have the power to shape a technology's course of progress
Benlian et al. (2015)	Empirical mixed methods	<i>How can platform providers encourage desirable behaviours by complementors (i.e., application developers) in the absence of formal roles and hierarchical control structures?</i> (p. 209)	Platform (ecosystem)	The role of perceived platform openness on complementors' behaviors

References	Type of research	Research question/ objective	Type of ecosystem	View on complementors and related concepts
Boudreau (2010)	Empirical quantitative	<i>how different approaches to opening a system influence the rate of innovation</i> (p. 1849)	Platform (ecosystem)	Strategies of opening up the platform when collaborating with complementors to ensure compatibility and interoperability of complementary components, and to boost complementary development. The independence of complementors may reflect in their initial reluctance of innovating on the platform
Boudreau (2012)	Empirical quantitative	<i>Understanding of the economic mechanisms shaping application software innovation, particularly as the number of producers grows</i> (p. 1410)	Platform (ecosystem)	Complementors are seen as developers that produce complementary application in a software context
Boudreau and Jeppesen (2015)	Empirical quantitative	<i>Does reliance on network effects and strategies to attract large numbers of complementors remain advisable in such contexts?</i> (p. 1762)	Platform (ecosystem)	Unpaid competing complementors are responsive despite the lack of sales incentives. But in this situation, the network effects are almost non-existent
Ceccagnoli et al. (2012)	Empirical quantitative	<i>(1) Is participation in a platform ecosystem, on average, associated with an increase in performance? (2) How is this improvement in performance affected by an ISV's ownership of IPRs and specialized downstream capabilities?</i> (p. 264)	Platform (ecosystem)	Commercialization of an innovation depends on downstream complementary capabilities, among others. Complementary assets are suggested to be vertically integrated. Complements or <i>complementary innovations</i> increase the platform's value. The interactions with complementors are a double-edged sword due to the duality of value co-creation and value capture. Platform owners also pose the risk of market entry for complementors; a constant risk that shape the cautious behavior of complementors, e.g., IPR protection



References	Type of research	Research question/objective	Type of ecosystem	View on complementors and related concepts
Cenamor et al. (2013)	Empirical quantitative	<i>Understanding of the role of complementary products within platform-based markets</i> (p. 406)	Platform (ecosystem)	Complements are seen “as strategic drivers of adoption in platform-based markets” (p. 405). Complementors may unlock and enhance the value of platforms. In-house complements provided by platform owner may impact the platform adoption differently
Cennamo (2018)	Empirical quantitative	<i>How next-generation leaders solve these coordination problems to generate value for users and how this solution later affects their market performance over time</i> (p. 3039)	Platform (ecosystem)	First- and third-party complements are critical in enhancing the value of the platform during the early development stage
Cennamo and Santaló (2013)	Empirical quantitative	<i>Hypothesis 1: All else equal, embracing apps market competition and apps exclusivity strategies with same intensity will lower platform performance.</i> (p. 1336) <i>Hypothesis 2: All else equal, platform performance will decrease at intermediate levels of distinctive positioning and increase at high and low levels of distinctive positioning.</i> (p. 1337)	Platform (ecosystem)	A large installed base of users on a platform results in a large number and variety of complements ( <i>interdependence</i> between users and complementary products). Availability of complements is one of the main determinants of platform’s value and market share. Managing complements is critical. The platform’s overall strategy influences complementors

References	Type of research	Research question/ objective	Type of ecosystem	View on complementors and related concepts
Cennamo et al. (2018)	Empirical quantitative	<i>How the tradeoffs complementors face when designing products for multiple platforms affect the quality performance of multihoming complements across platforms</i> (p. 462)	Platform (ecosystem)	The complexity of platforms negatively impacts the quality of the multihoming complements
Cennamo and Santaló (2019)	Empirical quantitative	<i>how this generativity's tension unfolds over time and affects user satisfaction</i> (p. 618)	Platform (ecosystem)	Fluctuations in platform's generativity affects complementor's value and their motivation to participate in that ecosystem. Due to their autonomy, complementors decide the level of investment and innovation efforts on complements. Indirect network effects are highlighted. But the value of each complement is different according to the users, who can imperfectly estimate it ex-ante. Complementors may take advantage of free riding, once there are enough first-rate complements. Or complementors may multihome, though this may create compatibility issues. These complementors' strategies may harm platform reputation
De Reuver, et al. (2018)	Review	<i>Develops a research agenda for digital platforms for dealing with these trends and research challenges</i> (p. 125)	Platform (ecosystem)	Complementors or third-party developers are understood as one of the main organizational elements of platforms

References	Type of research	Research question/objective	Type of ecosystem	View on complementors and related concepts
Eckhardt et al. (2018)	Experiment/model + empirics/simulation	<i>how the presence of certain types of information about entrepreneurial opportunities in a platform ecosystem is associated with commercialization rates among complementors</i> (p. 370)	Platform (ecosystem)	Complementors enhance the value of platforms through their complementary technologies
Foerderer et al. (2018)	Empirical quantitative	<i>If a platform owner like Google releases an app for its Android platform, does it keep app developers from innovating in the future?</i> (p. 444)	Platform (ecosystem)	Platform entry in complementary markets can have positive impact on complementors by providing new ideas and opportunities to innovate
Gawer (2014)	Conceptual/theoretical	<i>Technological platforms can be usefully conceptualized as evolving organizations or metaorganizations</i> (p. 1240)	Platform (ecosystem)	More complements attract more users. Sometimes complementors are seen as consumers because they develop on top of the platform. But this view neglects the competitive interactions between the complementors and the platform owner, the platform's impact on complementors' incentives to innovate. Since the ecosystem evolves, like any other actors, complementors can also hold multiple roles, which may change over time
Gawer and Cusumano (2014)	Review	<i>How [the literature on industry platforms] relates to managing innovation within and outside the firm as well as to dealing with technological and market disruptions and change over time</i> (p. 418)	Platform (ecosystem)	Identifying and collaborating with complementors is important. Opening up the platform motivates the complementors to innovate since it decreases their costs, but some resources should be kept proprietary

References	Type of research	Research question/ objective	Type of ecosystem	View on complementors and related concepts
Hannah and Eisenhardt (2018)	Empirical quantitative	<i>How do firms successfully balance competition and cooperation over time in ecosystems?</i> (p. 3165)	Ecosystem	Complementors are complementary component providers that may increase the innovativeness of a focal firm, differentiating from the rival companies. Complementors are further seen as an integral part of a firm's ecosystem strategy
Helfat and Rautbitschek (2018)	Conceptual/theoretical	<i>Specific types of dynamic capabilities can help platform leaders make decisions and take actions more effectively under these challenging conditions (...) some dynamic capabilities can help firms to not only create value, as is generally the focus of research on capabilities, but also capture value.</i> (p. 1392)	Platform (ecosystem)	<i>Complementary assets providers</i> (including <i>complementary products providers</i> , i.e., complementors) may pose threats to platform owners. <i>Complementary products providers</i> strictly refer to complementors, while <i>complementary assets providers</i> encapsulate more firms among which complementors are included. Continuous innovation realignment and integrative capabilities are needed between the platform and complementors
Jacobides et al. (2018)	Conceptual/theoretical	<i>When and why ecosystems emerge, and what makes them distinct from other governance forms</i> (p. 2255)	Ecosystem	Multilateral, nongeneric complementarities (unique and supermodular) are considered one of the building-blocks of ecosystems. The intensity of supermodular complementarities renders the level of ecosystem's resilience. Complements enhance the value of a product for customers. Complementors may or may not have a direct connection with the focal firm. But they are necessary actors in ecosystems and can originate from different industries. The collaboration between the focal firms and complementors affects the commercialization of a product/service

References	Type of research	Research question/objective	Type of ecosystem	View on complementors and related concepts
Kang and Downing (2015)	Conceptual/theoretical + empirics/simulation	<i>To explore the importance of the keystone effect for platform competition in the presence of indirect network effects</i> (p. 171)	Platform (ecosystem)	Complements impact the platform's installed base. In turn, the availability of complements is impacted by the strength of the keystone actor
Kapoor (2013)	Empirical quantitative	<i>shedding light on the different ways in which firms collaborate with complementors, and by exploring how the nature and the benefits of collaboration are influenced by the organizational and strategic contexts underlying firm-complementor relationships</i> (p. 4)	Business ecosystem	Complementors should not be seen or treated as buyers or suppliers, since they pose different challenges when interacting with them
Kapoor (2018)	Conceptual/theoretical	<i>Explicating the novelty and the usefulness of ecosystem-based theorizing</i> (p. 1)	Ecosystem	Complements are a key theoretical construct in business ecosystems that do not appear in strategic alliances or networks
Kapoor and Lee (2013)	Empirical quantitative	<i>How differences in the ways in which firms are organized with respect to complementary activities affect their decision to invest in new technologies</i> (p. 274)	Business ecosystem	The (type of) relationships with complementors are important for the focal firm in coordinating the changes the complements need to undergo when a new technology or upgrade is implemented
Kapoor and Agarwal (2017)	Empirical quantitative	<i>The extent to which a high performing complementor can sustain its superior performance within the [platform] ecosystem</i> (p. 531)	Business ecosystem with platform	Complementors in platforms are seen as holding the majority of the ecosystem, and essential to the value creation of the ecosystem. Complementors' value capture is impacted by the ecosystems' structure and evolutionary characteristics

References	Type of research	Research question/ objective	Type of ecosystem	View on complementors and related concepts
Karhu et al. (2018)	Empirical mixed method	<i>How do openness and related governance decisions render an ODP and its resources vulnerable to platform forking and how can the host use its resources to defend against it?</i> (p. 480)	Platform (ecosystem)	Besides the benefits of complementors' presence on a platform, the study presents a competition perspective on platform governance, i.e., platform forking. For complementors' governance, boundary resources are significant
Li (2009)	Empirical mixed method	<i>How Cisco Systems has been so successful in utilizing its strategy of mergers and acquisitions (MandA) for corporate growth</i> (p. 379)	Business ecosystem	Complementors through their products or services enable a focal firm to achieve a network value, rather than a product value. Complementors are seen as value-adding actors
Li and Agarwal (2017)	Empirical quantitative	<i>(1) What is the impact of the platform owner's integration strategy on consumer demand for the first-party application and third-party applications? (2) How does the integration strategy impact the overall demand in the complementary market?</i> (p. 3439–3440)	Platform (ecosystem)	Complementor integration by the platform owner can be beneficial to the entire complementary market
Nambisan et al. (2018)	Review	<i>how and when (under what circumstances) OI and platforms together may facilitate, hinder, or channel entrepreneurship</i> (p. 356)	Platform (ecosystem)	Through complementors, platform owners create value for the users. To facilitate this, platform owners share/provide resources to complementors, and other incentives to encourage innovation efforts and commitment

References	Type of research	Research question/ objective	Type of ecosystem	View on complementors and related concepts
Ozalp et al. (2018)	Empirical quantitative	<i>How do generational technological transitions affect disruption in platform ecosystems? And how do incumbent platforms navigate the process of disruption?</i> (p. 1204)	Platform (ecosystem)	A technologically advanced platform is a challenge for complementors, who have to experience steep learning curves and higher costs to timely develop and deliver compatible complements. Thus, the complement-development challenges also impact the platforms (i.e., complementors are essential to the platforms' success), while some complementors would opt for less challenging platforms
Parker and Van Alstyne (2018)	Experiment/model	<i>To achieve the highest growth rate, how open should that economy be? To encourage third-party developers, how long should their intellectual property interests last?</i> (p. 2015)	Platform (ecosystem)	The balance between platform openness and control impacts the complementors' behavior and ability to innovate
Rietveld and Eggers (2018)	Empirical quantitative	<i>how the evolution of a platform's user base from one dominated by early adopters to one dominated by late adopters affects performance outcomes for complementary products</i> (p. 305)	Platform (ecosystem)	The entry time of complementors in a platform ecosystem impacts the success of their complements. Besides the installed base of users, complementors' success on the platform is also impacted by heterogeneity in demand preferences and users' behavior

References	Type of research	Research question/objective	Type of ecosystem	View on complementors and related concepts
Rietveld et al. (2019)	Empirical quantitative	<i>How do platform sponsors choose the complements to promote and when to promote them?</i> (p. 1234)	Platform (ecosystem)	Selective promotion of complements by the platform owner is a strategic decision that can help the latter to possibly capture more value generated by the promoted complements on the platform, due to the more favorable or exclusive agreements between the platform owner and the complementors. Platform owner can influence the value of the ecosystem through selective promotion of complements. But this strategy can have various reasons and objectives
Scholten and Scholten (2012)	Empirical quantitative	<i>Identifying and categorizing control mechanisms leading platform owners in the ICT industry have implemented to steer external complementary innovation efforts on top of their platform</i> (p. 165)	Platform (ecosystem)	Through network effects, complementors and platforms become more valuable for the consumers. To ensure a certain complement quality, consistency, and reliability in the ICT industry, platform owners implement different control mechanisms that help to coordinate and manage complementors' innovation and development efforts
Teece (2018)	Conceptual/theoretical	Profiting from Innovation (PFI) framework in the digital economy and (platform) ecosystems	Platform (ecosystem)	There are different types of complementary assets that impact the value capture of an innovation in different ways. Complementary assets can either be produced in-house or by third parties. Either way will capture some value of the focal innovation. Complementors add up to the value of an innovation with their complements. Further research on complements and complementarity is needed. There are different types of complementarities; a concept that represents the essence of (platform) ecosystems



References	Type of research	Research question/ objective	Type of ecosystem	View on complementors and related concepts
Thomas et al. (2014)	Review	<i>A systematic review of the platform literature</i> (p. 198)	Platform (ecosystem)	Complementors are seen as independent, third-party actors that contribute to driving economies of innovation and complementarity in a platform setting
Tsujimoto et al. (2018)	Review	<i>First, what is the definition of the ecosystem in the field of management? Second, what are the main streams of ecosystem research? Third, has the ecosystem concept added new and significant value to management research?</i> (p. 49)	Ecosystem	Complementors are included in the heterogeneity of ecosystem actors that have their characteristics and motivations. Like all the other actors, complementors are believed to behave according to their own rationale and decision-making strategies. The heterogeneity of actors, interests, and behaviors may negatively impact the ecosystem's success
Wareham et al. (2014)	Empirical qualitative	<i>Research Question 1. How are the main tensions in technology ecosystems addressed in technology ecosystem governance? (...) Research Question 2. Tensions can manifest themselves as either contradictory or complementary logics. Are contradictory and complementary logics present in technology ecosystems? If so, how are they governed?</i> (p. 1196)	Platform (ecosystem)	Complements increase the value of a focal product. Complementors are autonomous actors whose output enhances the focal product's value, but they also admit to some sort of guidance or control imposed by the ecosystem leader

References	Type of research	Research question/ objective	Type of ecosystem	View on complementors and related concepts
Wen and Zhu (2019)	Empirical quantitative	<i>How app developers on the Android mobile platform adjust innovation efforts (rate and direction) and value-capture strategies in response to the threat of Google's entry into their markets</i> (p. 1336)	Platform (ecosystem)	Complementors are small firms that rely on platform resources to develop and offer their complements to users, and they are needed for platform health. Complementors face risks and challenges from the platform owner, e.g., the latter entry in complementary markets. But complementors react to even the mere entry threats by adjusting their value creation and capture strategies
West and Wood (2013)	Empirical mixed method	<i>How the firm [Symbian] built a complex ecosystem of stakeholders, evolved this ecosystem over its 10-year lifespan, and how limitations in its conception and leadership of this ecosystem limited its ability to respond to the iPhone and Android threats</i> (p. 30)	Platform (ecosystem)	Complementors are third-party complementary products that receive returns from the platform sponsor to ensure continuous supply of complements
Williamson and De Meyer (2012)	Conceptual/theoretical	<i>How a company can shape the structure and workings of its business ecosystem to simultaneously create and capture value, while minimizing the detrimental effects of surrendering hierarchy, vertical integration, and direct control?</i> (p. 25)	Business ecosystem	To ensure complementary investments, the focal firms have to find the proper ways to stimulate complementors' participation and commitment

References	Type of research	Research question/objective	Type of ecosystem	View on complementors and related concepts
Zhu and Iansiti (2012)	Experiment/model + empirics/simulation	<i>A formal model to examine conditions under which an entrant platform can survive the competition with an incumbent platform</i> (p. 90)	Platform (ecosystem)	Complementors are seen as developers of complementary applications contributing to network effects in the context of platforms
Zhu and Liu (2018)	Empirical quantitative	<i>Will we observe different patterns for platform-owner entries in such markets? Are platform owners more likely to target successful complementary products, or are they more likely to target underperforming complementary products, which are often less likely to be noticed, seeking to improve consumer satisfaction? How are consumers and complementors affected by platform-owner entries?</i> (p. 2620)	Platform (ecosystem)	Platform owners may enter the complementary market spaces for various reasons. Occasionally, this entry decision depends on the complementors' investments on the platform. But complementors can employ various strategies to impede platform owners from reaching that point, e.g., increase prices of complements, conceal information regarding their suppliers

**Acknowledgements** We appreciate the comments from the editor and the anonymous reviewer. We sincerely thank the participants of ISPIM conference 2020 for their valuable feedback on the initial draft of this article. We also acknowledge the funding support from the Sino-Danish Center for Education and Research (SDC) and the National Social Science Fund of China (No. 20&ZD075).

**Author contributions** All authors contributed to the study conception, design, and conceptualization of results. The material preparation and data collection were performed by AEC. The data was analyzed and synthesized by AEC and YH. The first draft of the manuscript was written by AEC, but all authors contributed to writing, reviewing, and editing of the manuscript. All authors read and approved the final manuscript.

**Funding** Open access funding provided by Aalborg University Library. This work was supported by the Sino-Danish Center for Education and Research (SDC) and the National Social Science Fund of China (No. 20&ZD075).

**Data availability** The bibliometric analysis dataset extracted from the two datasets, i.e., Web of Science and Scopus, and contents generated and analyzed during the current study are available upon reasonable request. The content analysis dataset is included in the Appendix 2.

## Declarations

**Conflict of interest** The authors have no competing interests to declare that are relevant to the content of this article.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

- Adner R (2006) Match your innovation strategy to your innovation ecosystem. *Harv Bus Rev* 84:98
- Adner R (2012) *The wide lens: A new strategy for innovation*. Penguin Group, New York
- Adner R (2017) Ecosystem as structure: an actionable construct for strategy. *J Manage* 43:39–58. <https://doi.org/10.1177/0149206316678451>
- Adner R (2021) *Winning the right game: how to disrupt, defend, and deliver in a changing world*. MIT Press, Boston
- Adner R, Kapoor R (2010) Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strateg Manag J* 31:306–333. <https://doi.org/10.1002/smj.821>
- Adner R, Kapoor R (2016) Innovation ecosystems and the pace of substitution: re-examining technology S-curves. *Strateg Manag J* 37:625–648. <https://doi.org/10.1002/smj.2363>
- Adner R, Lieberman M (2021) Disruption through complements. *Strategy Science* 6(1):1–19. <https://doi.org/10.1287/stsc.2021.0125>
- Afuah A (2000) How much do your competitors' capabilities matter in the face of technological change? *Strateg Manag J* 21:397–404. [https://doi.org/10.1002/\(SICI\)1097-0266\(200003\)21:3%3c397::AID-SMJ88%3e3.3.CO;2-T](https://doi.org/10.1002/(SICI)1097-0266(200003)21:3%3c397::AID-SMJ88%3e3.3.CO;2-T)
- Agarwal S, Miller CD, Ganco M (2023) Growing platforms within platforms: how platforms manage the adoption of complementor products in the presence of network effects? *Strateg Manag J* 44:1879–1910. <https://doi.org/10.1002/smj.3487>
- Alon I, Anderson J, Munim ZH, Ho A (2018) A review of the internationalization of Chinese enterprises. *Asia Pacific J Manag* 35:573–605. <https://doi.org/10.1007/s10490-018-9597-5>
- Aria M, Cuccurullo C (2017) bibliometrix: an R-tool for comprehensive science mapping analysis. *J Informetr* 11:959–975
- Bagheri SK, Di Minin A, Paraboschi A, Piccaluga A (2016) It's not about being generous: platform leaders and patent shelters. *Res Tech Manag* 59(2):28–35. <https://doi.org/10.1080/08956308.2015.1137195>
- Bengtsson M, Kock S (1999) Cooperation and competition in relationships between competitors in business networks. *J Bus Ind Market* 14:178–194. <https://doi.org/10.1108/08858629910272184>
- Bengtsson M, Kock S (2000) "Coopetition" in business networks—to cooperate and compete simultaneously. *Ind Mark Manage* 29:411–426
- Benlian A, Hilkert D, Hess T (2015) How open is this platform? The meaning and measurement of platform openness from the complementors' perspective. *J Inf Technol* 30:209–228. <https://doi.org/10.1057/jit.2015.6>

- Boudreau KJ (2010) Open platform strategies and innovation: Granting access vs. devolving control. *Manage Sci* 56:1849–1872. <https://doi.org/10.1287/mnsc.1100.1215>
- Boudreau KJ (2012) Let a thousand flowers bloom? An early look at large numbers of software app developers and patterns of innovation. *Organ Sci* 23:1409–1427. <https://doi.org/10.1287/orsc.1110.0678>
- Boudreau KJ, Jeppesen LB (2015) Unpaid crowd complementors: the platform network effect mirage. *Strateg Manag J* 36:1761–1777. <https://doi.org/10.1002/smj.2324>
- Brandenburger AM, Nalebuff BJ (1996) Co-opetition: 1 A revolutionary mindset that combines competition and cooperation 2. The Game Theory strategy that's changing the game of business, USA
- Bretas VPG, Alon I (2021) Franchising research on emerging markets: bibliometric and content analyses. *J Bus Res* 133:51–65. <https://doi.org/10.1016/j.jbusres.2021.04.067>
- Brusoni S, Prencipe A (2013) The organization of innovation in ecosystems: problem framing, problem solving, and patterns of coupling. *Adv Strateg Manag* 30:167–194. [https://doi.org/10.1108/S0742-3322\(2013\)0000030009](https://doi.org/10.1108/S0742-3322(2013)0000030009)
- Casadesus-Masanell R, Hałaburda H (2014) When does a platform create value by limiting choice? *J Econ Manag Strategy* 23:259–293. <https://doi.org/10.1111/jems.12052>
- Castro HR, Sant'Anna DALM (2023) Playing against the platform: a research note on the impact of exclusivity under vertical competition in video game platforms. *Technol Forecast Soc Change* 191:122501. <https://doi.org/10.1016/j.techfore.2023.122501>
- Ceccagnoli M, Forman C, Huang P, Wu DJ (2012) Cocreation of value in a platform ecosystem: the case of enterprise software. *MIS Q* 36:263–290
- Cenamor J, Usero B, Fernández Z (2013) The role of complementary products on platform adoption: evidence from the video console market. *Technovation* 33:405–416. <https://doi.org/10.1016/j.technovation.2013.06.007>
- Cennamo C (2018) Building the value of next-generation platforms: the paradox of diminishing returns. *J Manage* 44:3038–3069. <https://doi.org/10.1177/0149206316658350>
- Cennamo C, Santaló J (2013) Platform competition: strategic trade-offs in platform markets. *Strateg Manag J* 34:1331–1350. <https://doi.org/10.1002/smj.2066>
- Cennamo C, Santaló J (2019) Generativity tension and value creation in platform ecosystems. *Organ Sci* 30:617–641. <https://doi.org/10.1287/orsc.2018.1270>
- Cennamo C, Ozalp H, Kretschmer T (2018) Platform architecture and quality trade-offs of multihoming complements. *Inf Syst Res* 29:461–478
- Chu LY, Wu B (2023) Designing online platforms for customized goods and services: a market frictions-based perspective. *Acad Manag Rev* 48:78–99. <https://doi.org/10.5465/amr.2020.0247>
- Chung HD, Zhou YM, Ethiraj S (2023) Platform governance in the presence of within-complementor interdependencies: evidence from the rideshare industry. *Manage Sci*. <https://doi.org/10.1287/mnsc.2023.4706>
- Cobben D, Ooms W, Roijsackers N, Radziwon A (2022) Ecosystem types: a systematic review on boundaries and goals. *J Bus Res* 142:138–164. <https://doi.org/10.1016/j.jbusres.2021.12.046>
- Cournot AA (1838) Recherches sur les Principes Mathématiques de la Théorie des Richesses
- Cusumano MA, Gawer A (2002) The elements of platform leadership. *MIT Sloan Manag Rev* 62:51–58. [https://doi.org/10.1016/S0041-5553\(89\)80021-7](https://doi.org/10.1016/S0041-5553(89)80021-7)
- Davis J, Mengersen K, Bennett S, Mazerolle L (2014) Viewing systematic reviews and meta-analysis in social research through different lenses. *Springerplus* 3(1):1–9. <https://doi.org/10.1186/2193-1801-3-511>
- De Reuver M, Sørensen C, Basole RC (2018) The digital platform: a research agenda. *J Inf Technol* 33:124–135. <https://doi.org/10.1057/s41265-016-0033-3>
- de Vasconcelos Gomes LA, Facin AL, Salerno MS, Ikenami RK (2018) Unpacking the innovation ecosystem construct: evolution, gaps and trends. *Technol Forecast Soc Change* 136:30–48. <https://doi.org/10.1016/j.techfore.2016.11.009>
- Duriau VJ, Reger RK, Pfarrer MD (2007) A content analysis of the content analysis literature in organization studies: research themes, data sources, and methodological refinements. *Organ Res Methods* 10:5–34. <https://doi.org/10.1177/1094428106289252>
- Eckhardt JT, Ciuchta MP, Carpenter M (2018) Open innovation, information, and entrepreneurship within platform ecosystems. *Strateg Entrep J* 12:369–391. <https://doi.org/10.1002/sej.1298>
- Edgeworth FY (1897) Teoria Pura del Monopolio. *Giornale Degli Economisti* 15:13–31
- Eisenmann TR, Parker G, Van Alstyne M (2009) Opening Platforms: How, When and Why? In: Gawer A (ed) *Platforms, Markets and Innovation*. Edward Elgar, USA, pp 131–162

- Foerderer J, Kude T, Mithas S, Heinzl A (2018) Does platform owner's entry crowd out innovation? Evidence from Google photos. *Inf Syst Res* 29:444–460. <https://doi.org/10.1287/isre.2018.0787>
- Gaur A, Kumar M (2017) A systematic approach to conducting review studies: an assessment of content analysis in 25 years of IB research. *J World Bus* 12:145
- Gavel Y, Iselid L (2008) Web of science and scopus: a journal title overlap study. *Online Inf Rev* 32:8–21. <https://doi.org/10.1108/14684520810865958>
- Gawer A (2014) Bridging differing perspectives on technological platforms: toward an integrative framework. *Res Policy* 43:1239–1249. <https://doi.org/10.1016/j.respol.2014.03.006>
- Gawer A, Cusumano MA (2002) Platform leadership: how intel, microsoft, and cisco drive industry innovation. Harvard Business School Press, Boston, Massachusetts
- Gawer A, Cusumano MA (2014) Industry platforms and ecosystem innovation. *J Prod Innov Manag* 31:417–433. <https://doi.org/10.1111/jpim.12105>
- Gawer A, Henderson R (2007) Platform owner entry and innovation in complementary markets: evidence from intel. *J Econ Manag Strategy* 16:1–34. <https://doi.org/10.1111/j.1530-9134.2007.00130.x>
- Gnyawali DR, Charleton TR (2018) Nuances in the interplay of competition and cooperation: towards a theory of cooptation. *J Manage* 44:2511–2534. <https://doi.org/10.1177/0149206318788945>
- Granstrand O, Holgersson M (2020) Innovation ecosystems: a conceptual review and a new definition. *Technovation* 90:102098. <https://doi.org/10.1016/j.technovation.2019.102098>
- Hannah DP, Eisenhardt KM (2018) How firms navigate cooperation and competition in nascent ecosystems. *Strateg Manag J* 39:3163–3192. <https://doi.org/10.1002/smj.2750>
- Hart O, Moore J (1990) Property rights and the nature of the firm. *J Polit Econ* 98:1119–1158
- Hein A, Schreieck M, Riasanow T et al (2020) Digital platform ecosystems. *Electron Mark* 30:87–98. <https://doi.org/10.1007/s12525-019-00377-4>
- Helfat CE, Raubitschek RS (2018) Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems. *Res Policy* 47:1391–1399. <https://doi.org/10.1016/j.respol.2018.01.019>
- Hicks J (1970) Elasticity of substitution again: substitutes and complements. *Oxf Econ Pap* 22:289–296
- Hirshleifer J (1978) The private and social value of information and the reward to inventive activity. *Am Econ Rev* 61:561–574. <https://doi.org/10.1016/b978-0-12-214850-7.50038-3>
- Huo L, Qian Z, Shao Y, Jin Y (2021) A good match or a quarrel? Value co-creation between complementary manufacturers. *Tech Anal Strat Manag* 33(12):1450–1466. <https://doi.org/10.1080/09537325.2021.1876845>
- Iansiti M, Levien R (2004) The keystone advantage: What the new dynamics of business ecosystems mean for strategy, innovation, and sustainability. Harvard Business Press, Boston, Massachusetts
- Inoue Y, Tsujimoto M (2018) New market development of platform ecosystems: a case study of the Nintendo Wii. *Technol Forecast Soc Change* 136:235–253. <https://doi.org/10.1016/j.techfore.2017.01.017>
- Jacobides MG, Cennamo C, Gawer A (2018) Towards a theory of ecosystems. *Strateg Manag J* 39:2255–2276. <https://doi.org/10.1002/smj.2904>
- Kang J-S, Downing S (2011) Keystone effect on entry into two-sided markets: an analysis of the market entry of WiMAX. *Technol Forecast Soc Change* 94:170–186. <https://doi.org/10.1016/j.techfore.2014.09.008>
- Kang HY, Suarez FF (2023) Platform owner entry into complementor spaces under different governance modes. *J Manage* 49:1766–1800. <https://doi.org/10.1177/01492063221094759>
- Kang J-S, Lee H-Y, Tsai J (2011) An analysis of interdependencies in mobile communications technology: the case of WiMAX and the development of a market assessment model. *Technol Soc* 33:284–293. <https://doi.org/10.1016/j.techsoc.2011.10.002>
- Kapoor R (2013) Collaborating with complementors: What do firms do? *Adv Strateg Manag* 30:3–25. [https://doi.org/10.1108/S0742-3322\(2013\)0000030004](https://doi.org/10.1108/S0742-3322(2013)0000030004)
- Kapoor R (2018) Ecosystems: broadening the locus of value creation. *J Organ Des* 7:1–16. <https://doi.org/10.1186/s41469-018-0035-4>
- Kapoor R, Agarwal S (2017) Sustaining superior performance in business ecosystems: evidence from application software developers in the iOS and Android smartphone ecosystems. *Organ Sci* 28:531–551. <https://doi.org/10.1287/orsc.2017.1122>
- Kapoor R, Furr NR (2015) Complementarities and competition: unpacking the drivers of entrants' technology choices in the solar photovoltaic industry. *Strateg Manag J* 36:416–436. <https://doi.org/10.1002/smj.2223>

- Kapoor R, Lee JM (2013) Coordinating and competing in ecosystems: how organizational forms shape new technology investments. *Strateg Manag J* 34:274–296. <https://doi.org/10.1002/smj.2010>
- Karhu K, Gustafsson R, Lyytinen K (2018) Exploiting and defending open digital platforms with boundary resources: Android's five platform forks. *Inf Syst Res* 29:479–497. <https://doi.org/10.1287/isre.2018.0786>
- Li YR (2009) The technological roadmap of Cisco's business ecosystem. *Technovation* 29:379–386. <https://doi.org/10.1016/j.technovation.2009.01.007>
- Li Z, Agarwal A (2017) Platform integration and demand spillovers in complementary markets: evidence from Facebook's integration of Instagram. *Manag Sci* 63(10):3438–3458. <https://doi.org/10.1287/mnsc.2016.2502>
- Liang X, Luo Y, Shao X, Shi X (2022) Managing complementors in innovation ecosystems: a typology for generic strategies. *Ind Manag Data Syst* 122:2072–2090. <https://doi.org/10.1108/IMDS-12-2021-0809>
- Mantovani A, Ruiz-Aliseda F (2016) Equilibrium innovation ecosystems: the dark side of collaborating with complementors. *Manag Sci* 62:534–549. <https://doi.org/10.1287/mnsc.2014.2140>
- McIntyre DP, Srinivasan A (2017) Networks, platforms, and strategy: emerging views and next steps. *Strateg Manag J* 38:141–160. <https://doi.org/10.1002/smj.2596>
- McIntyre DP, Srinivasan A, Chintakananda A (2020) The persistence of platforms: The role of network, platform, and complementor attributes. Elsevier
- Milgrom P, Roberts J (1990) The economics of modern manufacturing: technology, strategy, and organization. *Am Econ Rev* 80:511–528
- Morgan L, Feller J, Finnegan P (2013) Exploring value networks: theorising the creation and capture of value with open source software. *Eur J Inf Syst* 22:569–588. <https://doi.org/10.1057/ejis.2012.44>
- Nambisan S, Siegel D, Kenney M (2018) On open innovation, platforms, and entrepreneurship. *Strateg Entrep J* 12:354–368. <https://doi.org/10.1002/sej.1300>
- Ozalp H, Cennamo C, Gawer A (2018) Disruption in platform-based ecosystems. *J Manage Stud* 55:1203–1241. <https://doi.org/10.1111/joms.12351>
- Parker G, Van Alstyne M (2018) Innovation, openness, and platform control. *Manag Sci* 64:3015–3032. <https://doi.org/10.1287/mnsc.2017.2757>
- Rietveld J, Eggers JP (2018) Demand heterogeneity in platform markets: implications for complementors. *Organ Sci* 29:304–322. <https://doi.org/10.1287/orsc.2017.1183>
- Rietveld J, Schilling MA (2021) Platform competition: a systematic and interdisciplinary review of the literature. *J Manage* 47:1528–1563. <https://doi.org/10.1177/0149206320969791>
- Rietveld J, Schilling MA, Bellavitis C (2019) Platform strategy: managing ecosystem value through selective promotion of complements. *Organ Sci* 30:1232–1251. <https://doi.org/10.1287/orsc.2019.1290>
- Rietveld J, Ploog JN, Nieborg DB (2020) Coevolution of platform dominance and governance strategies: effects on complementor performance outcomes. *Acad Manag Discov* 6(3):488–513. <https://doi.org/10.5465/amd.2019.0064>
- Ritala P, Almpantopoulou A (2017) In defense of 'eco' in innovation ecosystem. *Technovation* 60–61:39–42. <https://doi.org/10.1016/j.technovation.2017.01.004>
- Saadatmand F, Lindgren R, Schultze U (2019) Configurations of platform organizations: implications for complementor engagement. *Res Policy* 48:1–17. <https://doi.org/10.1016/j.respol.2019.03.015>
- Samuelson P (1974) Complementarity: an essay on the 40th anniversary of the hicks-allen revolution in demand theory. *J Econ Lit* 12:1255–1289
- Schmeiss J, Hoelzle K, Tech RPG (2019) Designing governance mechanisms in platform ecosystems: addressing the paradox of openness through blockchain technology. *Calif Manag Rev* 62(1):121–143. <https://doi.org/10.1177/0008125619883618>
- Scholten S, Scholten U (2012) Platform-based innovation management: directing external innovative efforts in platform ecosystems. *J Knowl Econ* 3:164–184. <https://doi.org/10.1007/s13132-011-0072-5>
- Shipilov A, Gawer A (2020) Integrating research on interorganizational networks and ecosystems. *Acad Manag Ann* 14:92–121. <https://doi.org/10.5465/annals.2018.0121>
- Snyder H (2019) Literature review as a research methodology: An overview and guidelines. *J Bus Res* 104:333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>
- Srinivasan A, Venkatraman N (2010) Indirect network effects and platform dominance in the video game industry: A network perspective. *IEEE Trans Eng Manag* 57:661–673. <https://doi.org/10.1109/TEM.2009.2037738>

- Su HN, Lee PC (2010) Mapping knowledge structure by keyword co-occurrence: a first look at journal papers in Technology Foresight. *Scientometrics* 85:65–79. <https://doi.org/10.1007/s11192-010-0259-8>
- Tauscher K, Rothe H (2021) Optimal distinctiveness in platform markets: leveraging complementors as legitimacy buffers. *Strateg Manag J* 42:435–461. <https://doi.org/10.1002/smj.3229>
- Teece DJ (1986) Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Res Policy* 15:285–305. [https://doi.org/10.1142/9789812833181\\_0005](https://doi.org/10.1142/9789812833181_0005)
- Teece DJ (2006) Reflections on “Profiting from Innovation.” *Res Policy* 35:1131–1146. <https://doi.org/10.1016/j.respol.2006.09.009>
- Teece DJ (2018) Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world. *Res Policy* 47:1367–1387. <https://doi.org/10.1016/j.respol.2017.01.015>
- Thomas LD, Ritala P (2022) Ecosystem legitimacy emergence: a collective action view. *J Manag* 48(3):515–541. <https://doi.org/10.1177/0149206320986617>
- Thomas LDW, Autio E, Gann DM (2014) Architectural leverage: Putting platforms in context. *Acad Manag Perspect* 28:198–219. <https://doi.org/10.5465/amp.2011.0105>
- Tian J, Zhao X, Xue L (2022) Platform compatibility and developer multihoming: a trade-off perspective. *MIS Q* 45:1661–1690. <https://doi.org/10.25300/MISQ/2022/16369>
- Tsujimoto M, Kajikawa Y, Tomita J, Matsumoto Y (2018) A review of the ecosystem concept—Towards coherent ecosystem design. *Technol Forecast Soc Change* 136:49–58. <https://doi.org/10.1016/j.techfore.2017.06.032>
- van der Geest C, van Angeren J (2023) Architectural generativity: leveraging complementor contributions to the platform architecture. *Calif Manage Rev* 65:71–92. <https://doi.org/10.1177/00081256231159398>
- Wareham J, Fox PB, Giner JLC (2014) Technology ecosystem governance. *Organ Sci* 25:1195–1215. <https://doi.org/10.1287/orsc.2014.0895>
- Weber R (1990) Basic content analysis, 2nd edn. SAGE Publications Inc, Newbury Park
- Weiss M, Gangadharan GR (2010) Modeling the mashup ecosystem: structure and growth. *R&D Manag* 40(1):40–49. <https://doi.org/10.1111/j.1467-9310.2009.00582.x>
- Wen W, Zhu F (2019) Threat of platform-owner entry and complementor responses: evidence from the mobile app market. *Strateg Manag J* 40:1336–1367. <https://doi.org/10.1002/smj.3031>
- West J, Wood D (2013) Evolving an open ecosystem: The rise and fall of the Symbian platform. *Adv Strateg Manag* 30:27–67. [https://doi.org/10.1108/S0742-3322\(2013\)0000030005](https://doi.org/10.1108/S0742-3322(2013)0000030005)
- Williamson PJ, de Meyer A (2012) Ecosystem advantage: How to successfully harness the power of partners. *Calif Manage Rev* 55:24–46. <https://doi.org/10.1525/cmcr.2012.55.1.24>
- Winter J, Battisti S, Burström T, Luukkainen S (2018) Exploring the success factors of mobile business ecosystems. *Int J Innov Tech Manag* 15(3):1850026. <https://doi.org/10.1142/S0219877018500268>
- Xu X, Venkatesh V, Tam KY, Hong S-J (2010) Model of migration and use of platforms: Role of hierarchy, current generation, and complementarities in consumer settings. *Manage Sci* 56:1304–1323. <https://doi.org/10.1287/mnsc.1090.1033>
- Yoffie DB, Kwak M (2006) With friends like these: the art of managing complementors. *Harv Bus Rev* 84(9):88–98
- Yoo DK, Roh JJ, Cho S, Yang MM (2022) Coopetition in a platform ecosystem: from the complementors’ perspective. *Electron Commer Res*. <https://doi.org/10.1007/s10660-022-09565-5>
- Zabel C, O’Brien D, Natzel J (2023) Sensing the Metaverse: The microfoundations of complementor firms’ dynamic sensing capabilities in emerging-technology ecosystems. *Technol Forecast Soc Change* 192:122562. <https://doi.org/10.1016/j.techfore.2023.122562>
- Zhang H, Hu Y, Shi X, Gao Y (2022) When and how do innovation ecosystems outperform integrated organizations? On technological interdependencies and ecosystem performance. *Ind Manage Data Syst* 122(9):2091–2120. <https://doi.org/10.1108/IMDS-11-2021-0720>
- Zhu F (2019) Friends or foes? Examining platform owners’ entry into complementors’ spaces. *J Econ Manag Strategy* 28:23–28. <https://doi.org/10.1111/jems.12303>
- Zhu F, Iansiti M (2012) Entry into platform-based markets. *Strateg Manag J* 33:88–106. <https://doi.org/10.1002/smj.941>
- Zhu F, Liu Q (2018) Competing with complementors: an empirical look at Amazon.com. *Strateg Manag J* 39:2618–2642. <https://doi.org/10.1002/smj.2932>
- Zhu J, Liu W (2020) A tale of two databases: the use of Web of Science and Scopus in academic papers. *Scientometrics* 123:321–335. <https://doi.org/10.1007/s11192-020-03387-8>



Zupic I, Čater T (2015) Bibliometric methods in management and organization. *Organ Res Methods* 18:429–472. <https://doi.org/10.1177/1094428114562629>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.