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RELATIONS BETWEEN ACTORS IN DIGITAL PLATFORM ECOSYSTEMS: A LITERATURE REVIEW

Research Paper

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Abstract

Digital platform ecosystems are a popular field of study in information systems and an economic structure of significant importance worldwide. However, we know little about what relations exist between and among actors on digital platforms. Findings of mutually beneficial interactions, cooperation, and value creation contrast findings of power, dependency, control, governance, rules, and competition in the ecosystem. To shed light on this issue, we conduct a structured literature review of information systems and management literature. In 144 studies, we find 19 different relations between and among platform owner, complementors, and end-users. We contribute to research in three ways. First, by discovering that instability of roles on digital platforms explains dual roles and the dynamics of roles more holistically than concepts that account for specific dual roles. Second, by finding weighting in the relations. Third, by observing nestedness of relations.

Keywords: Platform ecosystems, actors, roles, platform owner, complementors, end-users, relations.

1 Introduction

Digital platform ecosystems are increasingly subject to research in information systems (Reuver et al., 2018). In practice, their diffusion and impact are also apparent. Almost any person and organization connected to the internet maintains relations to or through digital platforms like Airbnb, Amazon, Instagram, Kickstarter, Twitter, or Upwork. A fundamental mechanism of digital platform ecosystems is that two or multiple independent actors affiliated to the platform owner interact to exchange and create value (Hagiu and Wright, 2015). Research refers to the actors' roles as the platform owner, complementors, and end-users. Complementors reside on multi-sided markets' supply side, while end-users reside on the demand side (Schreieck et al., 2016). Studies in information systems and management have identified various interactions between and among actors in digital platform ecosystems (Halckenhäusser et al., 2020; Mini and Widjaja, 2019). Systematizing these diverse relations between and among actors opens the opportunity to advance our understanding of digital platforms, provide an integration of existing knowledge, and identify research gaps.

A recurring theme in information systems literature is that platform owners and complementors cooperate and create value in reciprocal relations (Ceccagnoli et al., 2012; Ye and Kankanhalli, 2018; Rodon Modol and Eaton, 2021). Expressions of these relations are that platform owners motivate complementors or allow a certain degree of influence (Kretschmer et al., 2020; Gegenhuber et al., 2021). Contradicting these findings of mutually beneficial relations in platform ecosystems are findings of conflicts. These include, for example, power dependency between platform owners and complementors, privileging of one side of the market by the platform owner, or competition in the ecosystem (Cutolo and Kenney, 2021; Dou and Wu, 2021; Zhu, 2019). Also, possible imbalanced weighting in relations, such as uneven allocation of decisional authority in the control and rules

relation between platform owner and complementors, raises questions on relations' beneficiality (Ghazawneh and Henfridsson, 2013). While research addresses specific viewpoints, it remains unclear how contrasting conclusions on inter-platform relations are related and how they can integrate into a consistent picture of relations in digital platform ecosystems (Hurni et al., 2022; Stummer et al., 2018). As indicated above, relations always occur between actors. In some domains, the distinction between roles of actors involved in relations in digital platform ecosystems is unclear. For example, on sharing economy platforms, each actor can complement assets and consume assets (Bai and Velamuri, 2021). This ambiguity of actors' roles represents a conflict in systematizing relations. Tackling this problem would allow platform researchers to address the phenomenon of unclear distinctions between roles of actors involved in relations in digital platform ecosystems with greater comprehensiveness.

These current shortcomings – in systematizing the diverse relations, in explaining contrasting findings on inter-platform relations, and in differentiating the roles of actors involved in relations in digital platform ecosystems – reason that research comes short to understanding relations on digital platforms holistically. This incites to study the relations on digital platforms in more detail and motivates our research question: *Which relations exist between and among actors on digital platforms?*

To answer the question, we conducted a structured literature review in high-impact information systems and management literature. The search yielded 714 sources, in which we analyzed the relations between and among actors in digital platform ecosystems. We selected 144 publications that study intra-platform relations. The outcome of integrating the relevant findings are 19 different relations between and among actors on digital platforms categorized in six dimensions.

We discover that instability of roles on digital platforms comprehensively explains dual roles and the dynamics of roles. In comparison to concepts that account for specific dual roles, such as actors that consume and contribute on a platform, instability accounts for any combination of dual roles and the dynamics of roles. Therefore, instability of roles on digital platforms explains dual roles and the dynamics of roles more holistically. This is, for example, the prerequisite for describing roles and relations on decentralized platforms. Our second contribution is that we find an imbalance in the weighting in the relations on digital platforms. For example, we notice that there is a higher weighting of the end-user in the trust relation between complementors and end-users. Thirdly, we find nestedness of the relations between and among actors on digital platforms. Finally, we describe suggestions for future research.

The structure of this paper is as follows. The next section provides a brief background on digital platform ecosystems. The subsequent section explains the procedure of the structured literature research in detail. Afterward, we present the results, discuss the results in light of the literature and provide suggestions for future research directions.

2 Background

Digital platforms are sociotechnical systems that intermediate at least one supply side and one demand side through digital technology (Benbya et al., 2020; Parker et al., 2016). A platform owner commonly controls the platform (Karhu et al., 2018; Schrieck et al., 2022). Research refers to the role of actors on the supply side that co-create value as complementors and on the demand side as end-users (Schrieck et al., 2016; Eisenmann et al., 2009). Together, the platform owner, complementors, and end-users constitute a platform ecosystem (Kretschmer et al., 2020; Panico and Cennamo, 2020).

In digital platform ecosystems, complementors create complements offered to end-users via the platform (Hein et al., 2019). Key advantages for complementors to participate in platform ecosystems are reduced transaction costs enabled by simplified access to end-users and eased disposition of offerings by using resources the platform owner provides (Guo et al., 2021).

Researchers study complementors' activity to contribute under the term generativity and the resources the platform owner provides under the term boundary resources (Cennamo and Santaló, 2019; Ghazawneh and Henfridsson, 2013). End-users are responsible for consuming complementors' offerings accessible through the platform (Bai et al., 2019). Thereby they bring value to the platform

ecosystem. A platform owner ensures the economic viability of the platform, determines and enforces the conditions (rights, privileges, and duties) to participate, and continues to develop the platform (Hein et al., 2020; Heimburg et al., 2022; Ondrus et al., 2015; Eisenmann et al., 2009).

3 Design of the Literature Review

We reviewed publications that focus on digital platform ecosystems as a unit of analysis and contain explicit or implicit insights regarding the relations of actors. With these considerations in mind, we reviewed relevant publications and then coded the studies in terms of their findings on the relations in digital platform ecosystems in a concept-centric approach. Thereby we followed the guidelines of Webster and Watson (2002) and vom Brocke et al. (2009). Our endeavor can be classified as a scoping review that aims to better understand an evolving topic by systematizing the scope and ideas of various identified publications and by finding gaps (Wagner et al., 2021; Arksey and O'Malley, 2005).

We searched in the journals included in the Senior Scholars' Basket of Journals of the Association for Information Systems and the journals in the Financial Times' top 50 journals list. Furthermore, in line with Webster and Watson (2002), we searched in the proceedings of the International Conference on Information Systems since 2018 to include highly ranked IS papers with findings not yet published in journals, while keeping the dataset manageable. In a first iteration, we searched title, abstract, and keywords for "platform*" connected with an "AND" connector to "relation*" or six synonyms or expressions that represent relations between and among actors. The selected search terms aim to express different depths and lengths of the relations as well as different power structures in the relations. We used wildcards at the end of each keyword to account for various endings such as "interact", "interaction", and "interacting". This iteration returned 648 journal articles and 103 conference articles. In a second iteration, after looking at an initial set of results, we added the synonym "engag*" to the search string. This search query returned 713 journal articles and 122 conference articles. Table 1 summarizes our search strategy and illustrates the search string.

Outlet		Search			Hits	Selected			
AIS basket of eight IS journals	ISR	platform*	AND	relation*	69	12			
	MISQ			OR	collaborat*	56	9		
	ISJ			OR	interact*	21	7		
	JMIS			OR	depend*	41	7		
	JIT			OR	govern*	25	6		
	JAIS			OR	control*	27	5		
	EJIS			OR	coordinat*	22	3		
	JSIS			OR	engag*	14	3		
FT50 journal list	Manage Sci.			platform*	AND	relation*	65	7	
	J. Mark.					OR	collaborat*	20	6
	Strategic Man. J.					OR	interact*	27	6
	J. Manage Stud.					OR	depend*	16	5
	Organ. Sci.					OR	govern*	14	4
	Others					OR	control*	296	27
ICIS	Same search terms, in abstract, published since 2018					122	23		
Forward and backward search							14		
						Total	835		
							144		

Table 1. Summary of the literature search process.

We then screened the abstract of all 835 articles and identified 130 publications that focus on platform ecosystems as a unit of analysis and contain some explicit or implicit insight into the relations of actors in platform ecosystems. We explicitly considered the diversity of the relations in the very heterogeneous dataset of platform research. In case the information provided in the abstract was not sufficient to make a decision – for example because it did not state results or implications – we read the full text to decide on the inclusion of the respective article. We noticed that terms like "platform for further research", "relationship between variables", "control variable", or "collaborated with" particularly explain the delta between hits and selected results. Hereafter, in line with vom Brocke et al. (2009), we performed a forward and backward search based on the selected articles. This resulted in 14 articles that are concerned with the topic but were not captured with the search terms or articles in-press.

Following, we analyzed the 144 selected publications¹ to identify patterns and develop concepts (Webster and Watson, 2002). We coded along three main coding dimensions in an explorative coding process, which we repeated iteratively to develop conclusive coding constructs (Lacity et al., 2010). The first dimension represents the relation direction between and among actors' roles on platforms, namely between and among platform owner, complementors, and end-users. The dimension serves to categorize the relations, which represent this paper's concepts, into dimensions. The codes in this dimension quickly reached a plateau. The second dimension represents the relations that serve as concepts in our concept matrix (Table 3). Our codes in this dimension changed iteratively with the continuous integration of novel attributes and perspectives throughout coding. For empirical studies, we added the platform domain as a third dimension to understand its impact better.

4 Findings

4.1 Research domains and actors on digital platforms

The literature review reveals publications on the relations between and among actors on digital platforms across various domains of digital platform ecosystems. A consequence of the diversity of domains is that specific designations and assignment of roles to actors slightly differ. Table 2 illustrates the specific designations and assignment of roles to actors on the supply- and demand-side of platforms. For example, in the domain of e-commerce platforms, merchants or producers reside on the supply side, whereas buyers or institutional purchasers are on the demand side (Zhu and Liu, 2018; Leong et al., 2019). Nevertheless, regardless of their exact designation, actors on the supply side can be referred to as complementors and actors on the demand side as end-users.

Platform domain	Supply side (complementor)	Demand side (end-user)	Illustrative articles
Software (apps, operating system)	Developer, device manufacturer	User	Foerderer et al. (2018), Huang et al. (2018)
E-commerce	Merchant, producer	Buyer, institutional purchaser	Zhu and Liu (2018), Leong et al. (2019)
Gig/crowdwork	Worker, sourcee	Client, sourcer	Shafiei Gol et al. (2019), Taylor and Joshi (2019), Guo et al. (2021)
Crowdsourcing	Contestant, participant	Sourcer	Dissanayake et al. (2021), Boons et al. (2015)
Sharing economy	Provider, host	User, guest	Stofberg et al. (2021), Gerwe et al. (2020)

¹ Full list, including the publications not selected, available upon request

Social media	Content creator	Content consumer	Guan et al. (2021), Salehan et al. (2017)
Social shopping	Merchant, producer, creator	Buyer, institutional purchaser, consumer	Wang et al. (2020), Chen and Davison (2019)
Healthcare	Professional	Patient	Chen et al. (2019)
Crowdfunding	Project creator, entrepreneur	Funder, sponsor, backer	Thies et al. (2018), Wessel et al. (2017)

Table 2. Central domains of research and their designation of supply- and demand-side actors.

Next to the finding that complementors and end-users are diverse across domains of research, our literature review reveals heterogeneity among complementors and among end-users on a single platform (Wareham et al., 2014; Zuo et al., 2020; Eaton et al., 2015). On a given platform, complementors differ in terms of cultural background (Moser and Deichmann, 2020), by either extending or subverting a platform’s vitality (O’Mahony and Karp, 2020), and by their institutional structure. For example, on a social media platform, private users mainly complement content for their peers, while companies complement content for interacting with their customers (Matook and Brown, 2021). Analogous, on sharing economy platforms, end-users are heterogeneous in terms of civility (Ma et al., 2020) or level of enthusiasm (Ye et al., 2018).

Finally, a phenomenon in certain domains is that actors can occupy dual roles of complementor and end-user. Examples include social media platforms and sharing economy platforms. On social media platforms, each actor can complement and consume content (Rishika and Ramaprasad, 2019). On sharing economy platforms, each actor can complement assets and consume assets (Bai and Velamuri, 2021). Some researchers speak of “user innovations” to describe the phenomenon that certain end-users reveal innovations to a firm’s product platform (Jeppesen and Frederiksen, 2006). Others suggest the term “prosumers” to describe end-users that contribute something of value a platform (Darmody et al., 2017; Vesselkov et al., 2019).

4.2 Relations between and among actors on digital platforms

Figure 1 and Table 3 summarize our findings on the relations between and among the actors on digital platforms.

First, while researchers study the relations in different domains in which actors are designated differently, referring to actors on the supply side as complementors and actors on the demand side as end-users represents a common denominator. The mediating actor can be referred to as the platform owner (Kretschmer et al., 2020; Panico and Cennamo, 2020). Figure 1 illustrates actors with boxes and the roles they can occupy with bold text. Second, the figure illustrates findings of dual roles by connecting two different boxes (actors) with a dotted arrow. In this way, it integrates the findings that actors can occupy dual roles of complementor and end-user (Rishika and Ramaprasad, 2019; Bai and Velamuri, 2021) and that actors can occupy the complementor role in addition to the platform owner role, which we look at later (Zhu and Liu, 2018). Third, the literature review identified 19 different relations between and among actors on digital platforms categorized in six dimensions. Figure 1 illustrates the relation direction with the thick arrows and the relations identified in the literature review with lists of relations bulleted with triangles.

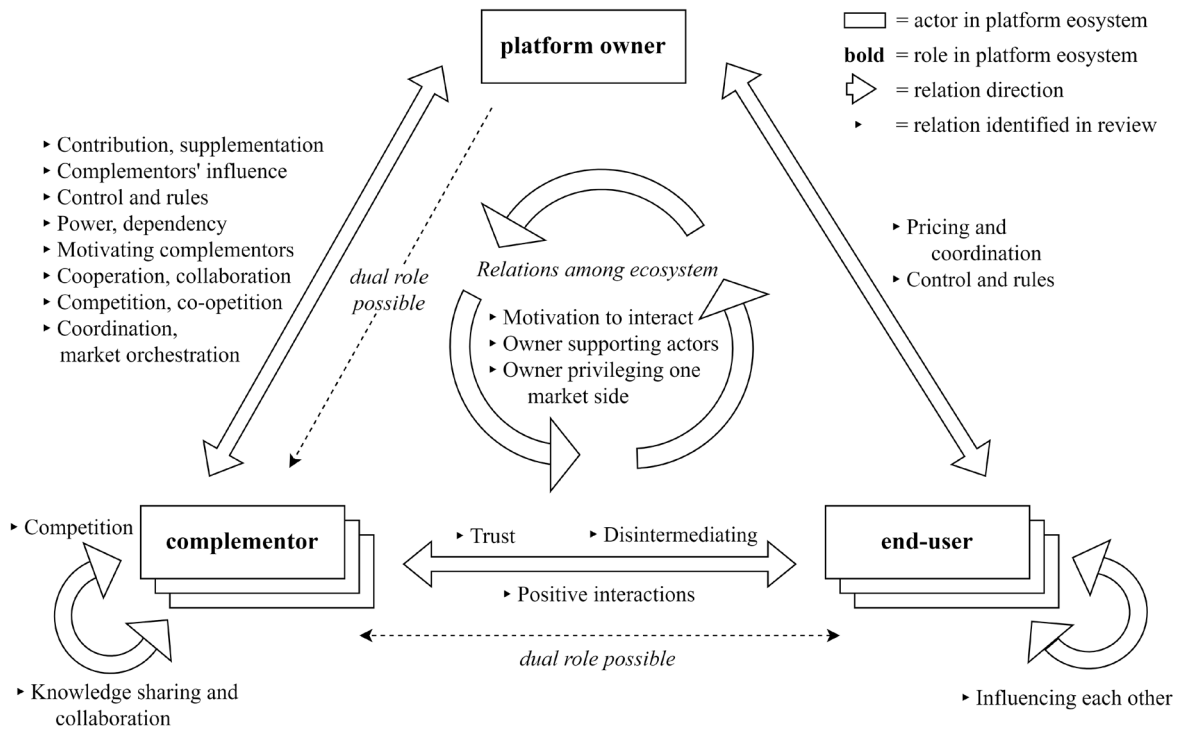


Figure 1. Actors, roles, and relations in digital platform ecosystems.

Table 3 deepens the understanding of these findings on which relations exist between and among actors on digital platforms. It is the centerpiece of our findings. Categorized in the six dimensions that represent the relation directions between and among actors, it denominates the relations, presents the number of papers in our sample of 144 articles, and provides illustrative studies.

Relation direction	Relations	No. of papers	Illustrative study
Between owner and complementors	Contribution, supplementation	19	Cennamo and Santaló (2019), Benlian et al. (2015)
	Complementors' influence	4	Gegenhuber et al. (2021), Eaton et al. (2015)
	Control and rules	41	(Ghazawneh and Henfridsson, 2013), Curchod et al. (2020)
	Power, dependency	7	Cutolo and Kenney (2021), Hurni et al. (2022)
	Motivating complementors	8	Song et al. (2021), Kuang et al. (2019)
	Cooperation, collaboration	5	Tiwana (2015b), Fieseler et al. (2019)
	Competition, co-opetition	5	Foerderer et al. (2018), Wen and Zhu (2019)
	Coordination, market orchestration	18	Parker and van Alstyne (2018), Hukal et al. (2020), Rietveld et al. (2019), Foerderer et al. (2021)
Between owner and end-users	Pricing and coordination	5	Banerjee et al. (2021), Bai et al. (2019), Shaw and Holland (2010)
	Control and rules	2	Ma et al. (2020), Guo et al. (2021)
Between complementors and end-users	Trust	9	Gu et al. (2021), Mittendorf et al. (2019)
	Disintermediating platform	3	Gu and Zhu (2021), Zhou et al. (2021)
	Positive interactions	15	Ludwig et al. (2021), Zhao et al. (2021)

Among an ecosystem	Motivation to interact	11	Burtch et al. (2019), Kozlenkova et al. (2021)
	Owner supporting actors	10	Guo et al. (2021), Luo et al. (2021)
	Owner privileging one market side	5	Thies et al. (2018), Dou and Wu (2021)
Among complementors	Competition	6	Heiland (2021), Miric et al. (2019)
	Knowledge sharing and collaboration	8	Foerderer (2020), Huang et al. (2018), Ma et al. (2018), Dissanayake et al. (2021)
Among end-users	Influencing each other	4	Susarla et al. (2016), Burtch et al. (2016), Thies et al. (2016)

Table 3. Findings of the structured literature review (concept matrix).

Relations between platform owner and complementors are subject to research in various papers that we grouped in eight relations. Research along the lines of complementor contributions or supplementations is the first recurring theme in this relation direction. The articles assigned to this relation focus on the generative, value-creating engagement of complementors on digital platforms (Cennamo and Santaló, 2019; Schreieck et al., 2021). One defining prerequisite for generativity is the openness of platforms (Benlian et al., 2015). Furthermore, researchers investigate affordances such as boundary resources that simplify value co-creation (Ghazawneh and Henfridsson, 2013; Ye and Kankanhalli, 2018; Petrik and Herzwurm, 2020). Some articles not only concern the contributions or supplementations but also relate this to the control and rules relation between platform owner and complementors (Ghazawneh and Henfridsson, 2013; Saadatmand et al., 2019).

Besides the theme of complementor contributions or supplementations, some scholars study the complementors' influence on the platform owner (Tiwana et al., 2010). One aspect is to understand how complementors impact the tuning of boundary resources (Eaton et al., 2015). Another aspect is research on the optimal strategy for addressing the influence of complementors (Gegenhuber et al., 2021; Ma et al., 2018).

A further theme of research on the relations between platform owner and complementors are studies on control and rules of platforms. While openness enables value co-creation, as explained above, complementors could exploit openness (Karhu et al., 2018). More specifically, without appropriate control, the actions of complementors might not align with the platform's objectives (Lee et al., 2018). This is especially critical due to tensions in platform ecosystems (Wareham et al., 2014). The majority of the articles identified concerns about optimal management of platforms by platform owners. In this context, platform owners must balance global ecosystem needs, and the local partnership needs to foster complementor dedication (Hurni et al., 2021). As an overarching tool to control platform openness, scholars investigate and theorize boundary resources (Ghazawneh and Henfridsson, 2013; Foerderer et al., 2019). Furthermore, we identify several studies of more concrete actions in the control and rules relation between platform owner and complementors. A possible tool to reduce free-riding of complementors are ex-ante rewards for complementors whose contributions benefit the ecosystem (Cennamo and Santaló, 2019). Another tool of control is the review of complementors' contributions. One article shows the negative effects of long processing times required by a platform owner to review apps that complementors want to publish on a platform (Song et al., 2018). Other scholars study evaluations of complementors as means of control in the relation direction between platform owner and complementors (Curchod et al., 2020). A related research topic is algorithmic control (Rahman, 2021; Wiener et al., 2021). Further areas of research are the effect of the strictness of regulation on participation (Gerwe et al., 2020) and performance (Wessel et al., 2017; Thies et al., 2018). Some articles relate control and rules to how the cooperation between platform owner and complementors is shaped (Tiwana, 2015b), the platform owner's coordination of complementors (Shafiei Gol et al., 2019), or trust between complementors and end-users. Concerning the last, a finding is that there can be a fusion of control and trust when end-users and platform owners form an implicit coalition in evaluation procedures (Curchod et al., 2020).

Emerging topics of research are control and rules on decentralized platforms. Their novel organizational form influences the control and rules relation between platform owner and complementors. This is because the design of the platform owner role is different. Platform ownership does not reside with one organization but is distributed across the ecosystem (Saadatmand et al., 2019). The potential of more decentralized control is expressed in the finding that its effect on complementors' attention and activity has an inverted U-shape (Chen et al., 2021b).

The power of platform owners and the dependency of complementors is another theme in research. In many cases, complementors depend on platform ecosystems to reach their end-users. Yet, as platforms also depend on complementors' contributions, power in platform ecosystems unfolds as a reciprocal process (Hurni et al., 2022). Perrons (2009) empirically finds that platform owners' relation to complementors is based on power and trust and that both can be used simultaneously in a way that benefits all of the stakeholders. At the same time, the power imbalance prevailing on many platforms allows platform owners to coerce complementors. For example, a platform owner hardly depends on an individual complementor as their resource investments are asymmetric. This has largely been overlooked, although it creates substantial risks and uncertainties for complementors (Cutolo and Kenney, 2021; Hurni et al., 2022). Therefore, some scholars investigate strategies that reduce dependency on platforms. Yet, strategies to reduce dependency, such as publicly denouncing the platform owner for discrimination or establishing an alternative platform, are risky and require bargaining power to come to fruition (Wang and Miller, 2020; Edelman, 2014). Finally, this relation is found to affect policymakers' considerations to regulate digital platforms (Cutolo and Kenney, 2021).

Researchers also investigate different aspects of how platform owners motivate complementors to follow their agenda. Kretschmer et al. (2020) find motivating complementors with appropriate incentives a central activity of platform owners (a) when establishing the platform and competing with traditional organizations (to start network effects), (b) when competing with other platforms (to differentiate while preventing that complementors switch or "multihome"), and (c) once different complementors are present (to motivate cooperation and value creation). A more specific finding is that for complementors, self-determination is an important factor in their relation to the platform owner (Goldbach and Kemper, 2014). Furthermore, gamification is found to be a tool for the platform owner to motivate complementors (Wang et al., 2021; Song et al., 2021). In the case of crowdsourcing, researchers find that feelings of pride and respect, which motivate complementors, can be increased by the way in which the platform owner communicates (Boons et al., 2015). Lastly, to motivate sharing of knowledge, financial incentives are found to result in knowledge sharing beyond the incentivized engagement (Kuang et al., 2019).

Cooperation and collaboration between platform owners and complementors is another identified relation. Since platform owners depend on complementors' contributions, researchers explore the conditions for long-term cooperation. In the case of an app store, a finding is that delegating decision rights to complementors weakens the benefits of decoupling an app from the platform, strengthens the benefits of standardizing interfaces to the platform, and reduces platform desertion (Tiwana, 2015b). Furthermore, fairness as perceived by complementors is another attribute of cooperation in the relation direction between platform owner and complementors (Fieseler et al., 2019). A further interest of research is the examination of cooperation over time (Rodon Modol and Eaton, 2021).

Nevertheless, the relation between platform owners and complementors also exhibits competition. This concurrency of cooperation and competition can be explained best with the concept "co-opetition" (Zhu and Liu, 2018). In the relation direction between platform owner and complementor, researchers study the entry of platform owners into complementors' spaces. Zhu (2019) finds diverse motivations and impacts of platform owners to compete with complementors. In e-commerce, platform owners target successful product spaces, which allows the assumption that the motivation is to capture value (Zhu and Liu, 2018). Yet, in the case of app stores, the motivation is to foster or shift complementors' innovation efforts (Foerderer et al., 2018; Wen and Zhu, 2019).

A final relation of this relation direction is coordination and market orchestration. It is related to the control relation presented earlier, as coordination can be an outcome of control (Shafiei Gol et al.,

2019). Researchers study platform owners' challenge to address tensions within complementors with its own interests (Leong et al., 2019), optimal levels of openness and intellectual property (Parker and van Alstyne, 2018), ways to signal where complementors should contribute (Hukal et al., 2020), and optimal compensation. One finding is that optimal compensation for complementors is complex and depends on various variables (Bai et al., 2019; Guda and Subramaniana, 2019). Furthermore, scholars find that platform owners can orchestrate complementors by strategically privileging specific complementors (Rietveld et al., 2019; Huber et al., 2017). Even though such privileging can be beneficial, it may have unintended consequences (Foerderer et al., 2021). Other researchers study how much end-user information platform owners should share with complementors. They recommend to either select a subgroup of sellers and truthfully share information with them or reduce the accuracy of information when sharing it with all complementors (Liu et al., 2021).

Relations between owner and end-users are subject to research in light of platform owners' role in pricing and coordination. Shaw and Holland (2010) develop a theoretical framework for a service platform that contains the coordination of end-users. One identified area of research concerns ways to improve matching end-users with suitable offerings. Accordingly, providing Q&A sections to end-users can improve matching (Banerjee et al., 2021). On the question of how to orchestrate demand on on-demand service platforms, researchers find that the optimal pricing of end-users is complex and depends on various variables like time and price sensitivity (Bai et al., 2019). Understanding optimal pricing becomes even more complex when considering stateful end-users that change their goodwill depending on the quality of their past interactions (Calmon et al., 2021).

A second area of research is the platform owner's relation to end-users in terms of control and rules. The literature review reveals that researchers study it in the sharing economy where complementors share assets with strangers. Scholars find that the terms and conditions platforms set are antecedents of customer civility (Ma et al., 2020). Furthermore, in crowdwork, clients are also found to have a need that platform owners govern complementors that offer their work (Guo et al., 2021).

Relations between complementors and end-users are subject to research in various papers that we grouped in three relations. The first group is the relation of trust between complementors and end-users. It is much concerned with the fact that platform intermediation injects trust in relations (Etzioni, 2019). Gu et al. (2021) identify rapport among stakeholders, reliability, facility quality, and share of value as factors influencing end-users' trust. For sharing economy platforms, scholars find that end-users' trust in the other market side matters more than complementors' trust (Mittendorf et al., 2019). Also, researchers find that end-users' trust in offerings increases when they see fraudulent reviews of complementors' offers marked as such rather than not seeing them (Ananthakrishnan et al., 2020).

The relation between complementors and end-users on digital platforms can culminate in disintermediating, i.e., interacting outside the platform. Scholars find that growing trust increases the likelihood of disintermediation (Gu and Zhu, 2021). Furthermore, on crowdwork platforms, disintermediation is more likely with high-quality, long-tenured complementors and when the complementor-end-user interaction frequency is high (Zhou et al., 2021). According to Edelman (2014), disintermediation reduces complementors dependence on powerful platforms.

Various articles concern the reasons for positive interactions between complementors and end-users. One aspect is the difference in cultural tightness across complementors and end-users. One of the findings is the negative effect of cultural differences on the relations (Chua et al., 2015). Guan et al. (2021) develop a model context-sensitive for the Chinese culture that focuses on the impact of end-users' social perceptions with regard to the complementor and other end-users on the success of streamers (complementors) to sell virtual gift cards in live streaming. Again in live streaming, Zhao et al. (2021) find empirically that, among others, social affordance (e.g., profile building affordance and social interactivity) is positively associated with the popularity of complementors. A study of a crowdfunding platform reveals that end-user psychological ownership leads to success in crowdfunding. One finding is that perceived control and intimate knowing can lead to psychological ownership (Zheng et al., 2018). Another finding is that both, providing too little and too much information to end-users, can harm complementors on group buying e-commerce platforms. Thus,

complementors need to identify an optimal level of information provided (Xu, 2018). In addition, concerning information sharing with the other market side, a study analyzed finds asymmetries between complementors and end-users in the optimal amount of information provided on crowdwork platforms. End-users attract more bids from crowdworkers when they provide moderate degrees of task concreteness, whereas high concreteness increases crowdworkers' success (Ludwig et al., 2021). Finally, with a relational model view, Stofberg et al. (2021) investigate complementors' and end-users' perceptions of sharing economy platforms relations. They find that equality matching and communal sharing foster prosocial behavior and the willingness to continue participating.

Relations among an ecosystem include all findings on triangular relations between platform owner, complementor, and end-user. In our sample, we identified 11 papers on motivations to interact in a digital platform ecosystem. Chen et al. (2018) find that mechanisms motivating actors, implemented through IT artifacts, work differently depending on the level of motivation. One paper finds that platforms that offer a reward system through which end-users can reward complementors, may profit from more frequent and richer content from the intensified use. Yet, the novelty of content decreases (Burtch et al., 2019). Similar to rewards, also "follows" of end-users have a positive effect on complementors' contributions (Moqri et al., 2018). The motivations of actors on sharing economy platforms are found to differ across countries. This is due to different levels on Maslow's hierarchy of needs and levels of social inequality and generalized trust. Accordingly, platform owners need to adjust the platform mechanisms and rules (Kozlenkova et al., 2021). Also, for sharing economy platforms, the impact of the relationship between face-to-face interaction between providers and users and the governance by platform owners on participation is explored (Gerwe et al., 2020). Finally, Salehan et al. (2017) draw on the motivation-participation-performance framework to identify motivations to interact on social media platforms.

Researchers also study the relation among the ecosystem in terms of how the platform owner supports the ecosystem. Researchers find that the long-term success of platforms requires that platform owners engage with all stakeholders and that the platform owner designs elements that purposefully guide ecosystem actor behavior towards specific choices (Barrett et al., 2016; Briel and Davidsson, 2019). A key aspect of the relation that a platform owner supports actors among the ecosystem is to develop trust and commitment in the triadic relationship. Drawing on transaction cost economics, Guo et al. (2021) find that platform owners must establish mechanisms to develop trust and commitment. On a more practical layer, one mechanism found to be successful are bilateral reviews. They are beneficial in the decision process for all market sides (Chen et al., 2021a). A further finding is that buyer protection insurance supports both end-users and complementors as it significantly increases buyer spending and seller revenue (Luo et al., 2021). Researchers also begin to study the question of how to develop trust and commitment in the triadic relation in the case of recently emerging decentralized platforms (Perscheid et al., 2020; Chen et al., 2021b). Finally, this identified relation that the platform owner supports the ecosystem is closely linked to the control and rules relation between platform owner and complementors, the control and rules relation between platform owner and end-users, and the trust relation between complementors and end-users.

Owner privileging one market side is the third theme in research on the relations among an ecosystem. A finding is that network effects can be asymmetric, i.e., a growing number of actors on one market side is more beneficial to the platform ecosystem than growth on another market side (Thies et al., 2018). Also, sometimes actors on one market side only use one platform ("single-homing"), which makes anyone aiming to interact with these actors dependent on the platform (Dou and Wu, 2021). Both turn actors or an entire market side into critical resources (Sun and Tse, 2009). Therefore, platform owners may privilege or subsidize the market side that is more beneficial or single-homes. In this context, scholars investigate both pricing and non-pricing strategies to privilege (Dou and Wu, 2021). This relation is related to the coordination and market orchestration relation between platform owner and complementor.

Relations among complementors are subject to research in light of a competition relation among complementors. This relation is in the very nature of platforms as quasi-markets in which complements compete for end-user demand. Generally, competition among complementors results in

platforms' ability to ensure efficiency and reliability (Heiland, 2021). Still, complementors apply formal and informal mechanisms to protect their digital assets from appropriation by competitors (Miric et al., 2019). Tiwana (2015a) examines intra-platform competition more closely and presents a mid-range theory of how the complementarity between input control and modularization of a platform extension – by inducing evolution – affects its performance in a platform market.

However, also knowledge sharing and collaboration among complementors characterize the relations among complementors. Dissanayake et al. (2021) find that complementors cooperate by sharing knowledge while competing. Applying social exchange and social capital theories, they find knowledge shared by other complementors positively impacts their contest performance in crowdsourcing. A similar effect occurs on software platforms where knowledge exchange among complementors stimulates innovation in the form of major app updates that receive positive end-user feedback (Foerderer, 2020). Huang et al. (2018) find that complementor knowledge contributions can be stimulated with knowledge seeding by the platform owner. In the domain of crowdwork, researchers find that complementors' active participation in knowledge sharing communities reduces their desire to quit working in the crowdworking environment (Ma et al., 2018). Likewise, in crowdwork, drawing on resource dependence theory, scholars reveal that complementors, in some cases, actively oppose organizing solutions of the platform by organizing (Karanović et al., 2021). Finally, other scholars study how cultural differences affect knowledge sharing and collaboration among complementors (Moser and Deichmann, 2020).

Relations among end-users are examined in terms of the mutual relation to influence each other. In a study of a crowdfunding platform, Burtch et al. (2016) find that it has a negative influence on subsequent visitors' likelihood of conversion when campaign contributors elect to conceal user name or contribution amount. Another finding is that overall popularity information has a positive effect on end-users' funding behavior (Thies et al., 2016). Other researchers study the role of word-of-mouth communications on platforms. For a video sharing platform, scholars find that factors related to a complementor's ability to be a connector and a translator likely result in word-of-mouth communications among end-users (Susarla et al., 2016).

5 Discussion and Future Research Directions

This paper illustrates the high degree of diversity of relations between and among actors on digital platforms. We find 19 different relations categorized in six dimensions (relation directions). A distinguishing feature of this paper is the holistic approach we especially achieve by focusing on all roles, relations, and viewpoints in digital platform ecosystems. This distinguishes the paper from existing reviews, for example in the area of platform governance (Halckenhäusser et al., 2020; Schreieck et al., 2016). Overall, we do not identify major conflicts in existent research. Yet, we find an imbalance of existing works' perspectives as we categorize the identified papers into different relation directions: 107 papers address relations in the “between owner and complementors” relation direction, while 78 papers deal with all other relations combined.

Our systematization may serve as a foundation for scholars and practitioners to understand the complexity of relations in digital platform ecosystems. It also provides entry points for future studies. On the one hand, it offers the opportunity to identify unfilled gaps or previously under-researched areas (e.g., relations with low research penetration) and to consider them as targets for future research. On the other hand, it invites researchers to confirm, extend, or falsify previous findings through studies in other areas or with alternative research setups. Our contributions to research are threefold. We identify the instability of roles on digital platforms, weighting in the relations on digital platforms, and nestedness of the relations between and among actors on digital platforms.

5.1 Instability of roles on digital platforms

This paper contributes to research with the finding that roles on platforms are instable. As we presented, some platforms exhibit dual roles of complementor and end-user. For example, on social

media platforms, actors can complement and consume content (Rishika and Ramaprasad, 2019). Similarly, on sharing economy platforms, actors can complement and consume assets (Bai and Velamuri, 2021). To explain this phenomenon of dual roles, some scholars refer to “user innovations” or the term “prosumer” (Jeppesen and Frederiksen, 2006; Vesselkov et al., 2019; Darmody et al., 2017; Gregory et al., 2021). Furthermore, our findings on the competition and co-opetition relation between platform owner and complementors show that a platform owner can become a complementor on its platform (Zhu and Liu, 2018). This dual role of platform owner and complementor, or “dual process of platformization and infrastructuring” is referred to and explained with the term “vertical integration” and is increasing in relevance (Constantinides et al., 2018, p. 388).

We argue that each of the concepts only accounts for a subset of dual roles and both fail to account for the dynamics of roles. We believe instability of roles on digital platforms explains dual roles and the dynamics of roles more holistically. On the one hand, acknowledging instability of roles considers that an actor can have different roles (e.g., complementor and end-user or platform owner and complementor) at the same time. This flexibility in the role combinations is important as platforms may exhibit other combinations of dual roles. For example, on decentralized platforms, complementors and end-users may also handle tasks that attribute to the platform owner role (Chen et al., 2021b). On the other hand, acknowledging instability of roles on digital platforms also considers the underlying dynamics of roles. While the dual role platform owner and complementor is likely a situation of longer duration as platform owners separate departments or establish separate bodies of organization, the dual role complementor and end-user can be very dynamic (Zhu and Liu, 2018). A complementor becomes an end-user for an indefinite time and the other way around. Furthermore, instability of roles on digital platforms also considers that, instead of adopting dual roles, actors might also change roles and therefore abandon the old role for an undefined time. Finally, again on decentralized platforms, dynamics of roles are probably manifested differently.

Seeing platform actors through an instability lens can help better understand the plurality of relations between and among actors in digital platform ecosystems. For example, the term user is sometimes used to account for both consumption and contribution of something of value (Burtch et al., 2019; Wang et al., 2021). Furthermore, the instability could also influence the dynamics in complex ecosystems (Wang, 2021). We believe that recognition of the fact that roles on platforms are instable simplifies the understanding of mechanisms of digital platforms.

A suggestion for a further research direction is to better understand the consequences of instability. Following early research on the influence of the decision of a platform owner to also become complementor on its platform on complementors’ innovativeness (Foerderer et al., 2018), we suggest researching further consequences. An assumption is that the consequences of role instability vary depending on the relation direction in which it occurs. Accordingly, it likely positively influences network effects if a complementor becomes an end-user on the platform it contributes. For example, on a crowdwork platform, complementors that accept large assignments, split them into smaller jobs, and subcontract those to complementors on the platform may strengthen demand. In the case that end-users are instable and create complements of any kind (e.g., content, products, or innovations extending the platform), it may also be favorable for the platform owner as it can co-create value (Kuang et al., 2019). If an actor is platform owner and at the same time complementor on its platform, other complementors may suffer from an unfair disadvantage (Khan, 2016). Finally, we suggest developing a method for measuring the instability of actors. The ability to measure the degree of instability of each actor could inform the competitive strategy of platform owners and complementors.

5.2 Weighting in the relations on digital platforms

Regarding the relations identified, a contribution to research is the discovery of weighting in the relations between actors. Several relations between platform owner and complementors that have been studied indicate an imbalance in the weighting of relations, e.g., an unequal distribution of decision-making power among actors (Halckenhäusser et al., 2020; Mini and Widjaja, 2019; Schrieck et al., 2016; Mukhopadhyay and Bouwman, 2019). We find imbalance in the weighting in several relations.

The asymmetries in the control and rules relation, competition and co-opetition relation, and coordination and market orchestration relation demonstrate a higher weighting of the platform owner (Ghazawneh and Henfridsson, 2013; Zhu and Liu, 2018; Hukal et al., 2020). We also find imbalance in the weighting in the pricing and coordination relation between platform owner and end-users. This relation demonstrates a higher weighting of the platform owner (Bai et al., 2019). In addition, we notice imbalanced weighting in the trust relation between complementors and end-users. For instance, a study shows that end-users' trust in the other market side matters more than complementors' trust, indicating a higher weighting of the end-user in the trust relation (Mittendorf et al., 2019). Our contribution warrants to progress toward deepening the understanding of the weighting of the roles in the relations between actors on digital platforms. We suggest exploring the individual facets of the imbalance in the weighting in more detail to advance this issue. Besides, viewing the mechanisms and asymmetries of power on digital platforms from this angle could contribute to the current debate on stricter regulation of digital platforms.

In the quest of understanding weighting, the architecture of a digital platform likely plays a role. Accordingly, explanatory models for alternative structures of platforms, such as for a model that distinguishes between a platform provision and a platform sponsorship actor, likely deviate from a model that only includes a platform owner (Eisenmann et al., 2009). Similarly, fully decentralized platforms as a specific architecture of digital platforms likely exhibit idiosyncrasies in terms of the weighting of roles in relations. In our sample, only Saadatmand et al. (2019), Perscheid et al. (2020), and Allen et al. (2020) investigate the impact of decentralization on relations between actors on digital platforms. We believe relations between and among actors on digital platforms could fundamentally change through the adoption of decentralized platform architecture. Therefore, we propose researching the impact and potential of decentralization on weighting in the relations on digital platforms.

5.3 Nestedness of platforms

Finally, we contribute to research by displaying nestedness of the relations between and among actors on digital platforms. For example, we illustrate how the control and rules relation between platform owner and complementors relates or even overlaps with the trust relation between complementors and end-users in the form of the implicit joint evaluation procedures (Curchod et al., 2020). The fact that existing research and existing literature reviews on platform governance link several relations identified in this review, for example control, pricing, and cooperation, reflects this finding (Halckenhäusser et al., 2020; Mukhopadhyay and Bouwman, 2019; Schreieck et al., 2016). Possibly, platform governance is present across relations. We propose to examine this phenomenon more closely in future research, ideally, in a controlled setting that allows recognizing precise interrelations.

5.4 Limitations

Our results underlie some limitations. First, the literature review might not cover all relevant studies due to the choice of outlets and keywords. For example, studies with insights on relations not published in high-impact outlets or not described by the term relation or one of its synonyms might fall out of our scope. Second, in the course of our coding process, which allowed grouping the studies' findings in 19 relations, some insights might have been lost. For example, we did not distinguish between transaction and innovation platforms due to the conflict of scope and abstraction (Cusumano et al., 2019). Therefore, a more granular coding, possibly recognizing distinctions in the type of platforms, might generate a more precise division of research directions. Third, like other synthesizing works on digital platforms, this paper reduces actors to the roles platform owner, complementors, and end-users. While we focus on understanding relations comprehensively across platform ecosystems, follow-up research could consider heterogeneity of actors in a more differentiated way (Deilen and Wiesche, 2021). Relations may differ when, for example, distinguishing between B2B and B2C platforms, developers and marketplace sellers, or business and private customers. Finally, our perspective and perceptions might influence the suggestions for future research directions. Therefore, we invite fellow researchers to use our findings as a starting point for their research.

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