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How Access to Resources Affects Complementor Innovation in Platform Ecosystems

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ABSTRACT

Platform owners must ensure that the ecosystems around their platforms remain as innovative as possible to meet market needs and keep pace with competing platform ecosystems. To this end, platform owners either attract new complementors with innovative complements or foster innovation among existing complementors. This study takes the perspective of complementors to understand the conditions under which access to the platform owner's resources contributes to the complementor's innovativeness. Based on survey data from 179 complementors of different software ecosystems, our findings support the supposition that access to the platform owner's valuable technical and commercial capital drives the complementor's product and process innovativeness. When it comes to access to social capital (e.g., reputation effects, quality signaling), benefits for innovation (limited to production innovation) only accrue under the condition that the platform owner invests in partner-specific information sharing. Our findings contribute to a better understanding of the role of platform design and partnership management practices by the platform owner in shaping complementor innovation.

Keywords: Platform Ecosystems, Governance, Innovation

INTRODUCTION

In recent years, platform ecosystems have become the dominant organizational arrangement through which innovative software products and services are created (Evans et al., 2008; Iansiti & Levien, 2004). As a consequence, major software companies like Apple, Google, Microsoft, or SAP have become platform owners that offer certain resources and capabilities to 3rd-party developers, including a platform with core functionality and application programming interfaces (APIs), development environments, and channels for app distribution (Eaton et al., 2015; Tiwana, 2013; Wareham et al., 2014). Referred to as complementors (Huber et al., 2017; Hurni et al., 2022; Hurni et al., 2020) or spokes (Kude et al., 2012), these partners use these platform resources to provide innovative add-on functionality and services that build on and extend digital platforms (Boudreau, 2012; Eaton et al., 2015). While past research has established that the technological, commercial, and social resources offered by the platform owner will influence the complementor‘s motivation to partner with a platform owner (Ceccagnoli et al., 2012; Kude et al., 2012; Tiwana, 2015), little is known about the impact that such different types of resources may have on the cocreation of innovation in platform partnerships (Hein et al., 2019). This lack of understanding is an important gap because the promise of generativity requires complementors to join a platform and use the resources offered by the platform owner to create innovation (Evans et al., 2008; Iansiti & Levien, 2004).

Our study addresses this gap by theorizing and testing how the access to different types of resources offered by the platform owner (i.e., technological, commercial, and social) affects two types of innovation: Product innovation and process innovation. Informed by the firm’s resource- and knowledge-based views, we hypothesize that the effect of the access to technological, commercial, and social resources on innovation will vary with the degree to which the platform

owner engages in information exchange with the complementor. We test our hypotheses using survey data from 179 complementors. Our findings show that access to the platform owner‘s technological and commercial capital is critical for product and process innovation. By contrast, social capital does not have significant main effects on process and product innovation. However, social capital contributes to product innovation when the platform owner exchanges extensive information with the complementor. Our findings contribute to the literature on platform ecosystems and input-oriented theories of inter-firm partnerships.

The remainder of this chapter is organized as follows. First, we review the theoretical and conceptual background to develop our hypotheses. Then, we describe our method before presenting our results. We conclude by discussing our results, elaborating on theoretical contributions and implications for practice, and addressing the limitations of our study.

THEORETICAL AND CONCEPTUAL BACKGROUND

Platform Ecosystems: Resources as Input, Innovation as Outcome

The input-oriented perspective of platform ecosystems holds that 3rd-party developers partner with a platform owner to access resources and capabilities that they lack, but the platform owner possesses (Kude et al., 2012). In the spirit of this input-oriented perspective, much research on platform ecosystems has pointed to the importance of boundary resources such as a digital platform with core functionality and application programming interfaces (APIs), development environments, knowledge resources, technical support, marketing material, and a channel for app distribution (Eaton et al., 2015; Tiwana, 2013; Wareham et al., 2014). Such boundary resources are created and provided by the platform owner and made accessible only to those complementors that join an ecosystem (Huber et al., 2017; Kude et al., 2012; Sarker et al., 2012; Wareham et al., 2014). Whether or not complementors will join an ecosystem hinges on

providing three types of resources, i.e., the platform owner‘s technological, commercial, and social capital (Kude et al., 2012). Building on Kude et al. (2012), we refer to *technological capital* as the technical resources that the platform owner makes available to complementors, which most importantly includes a modern, extensible platform that integrates with 3rd-party products and services. We refer to *commercial capital* as the resources provided by the platform owner to enable complementors to address better or penetrate different markets. For example, distribution channels like the app store allow complementors to address new customers by giving access to a global audience. Moreover, platform owners sometimes provide standardized marketing tools and materials or provide monetary support for campaigns to help complementors access new sources of revenue (Huber et al., 2017). Finally, we refer to *social capital* as the resources that enable complementors to benefit from the platform owner’s reputation. For example, reviewed and curated app stores or certificates issued by the platform owner are often regarded as positive signals for quality and reliability, helping complementors to benefit from the platform owner‘s reputation.

Across partner dyads, the exploitation of technological, commercial, and social resources will vary for three reasons. First, each platform owner offers a set of resources to their ecosystems to systematically vary across ecosystems. Second, although some resources are available to all complementors within an ecosystem, platform owners may choose to give different complementors different levels of access to resources, e.g., in response to their partner level (Huber et al., 2017; Hurni et al., 2022; Wareham et al., 2014). Third, even if resources are identical, the extent to which complementors access (i.e., make use of) the resources is likely to vary due to the heterogeneity of complementor resources with which they need to be combined and integrated. The resources and capabilities of complementors are often highly idiosyncratic, as expressed by their usually narrow yet deep expertise about specific industry niches, use cases, or

technologies (Ceccagnoli et al., 2012; Foerderer et al., 2019; Huber et al., 2017; Kude et al., 2012). Therefore, even if complementors are members of the same ecosystem, they vary in how they access specific resources provided by the platform owner. Therefore, our study focuses on the extent to which individual complementors access specific platform resources rather than on the availability of resources in an ecosystem. This complementor-centric perspective is previously under-researched (McIntyre & Srinivasan, 2017).

The notion of 'generativity'—widely seen as the key promise of platform ecosystems (Evans et al., 2008; Iansiti & Levien, 2004)—is closely related to the input-oriented perspective (Kude et al., 2012). The basic idea is that through platform partnerships, 3rd-parties can access complementary resources that they could not have created themselves and that they can then use these resources to create often surprising outside innovation (Boudreau, 2012; Foerderer et al., 2018; Foerderer et al., 2019; Huber et al., 2017). The literature distinguishes between two types of (outside) innovation: Product and process innovation (Adner & Levinthal, 2001; Tarafdar & Gordon, 2007; Trantopoulos et al., 2017). In our context, product innovation refers to creating a 3rd-party software product or service that is new or has considerably improved characteristics, while a process innovation refers to a new or significantly enhanced software development or delivery method.

Hypotheses Development

While much research has acknowledged the importance of platform resources in general (Eaton et al., 2015; Ghazawneh & Henfridsson, 2015; Wareham et al., 2014), the specific impact that these resources may have on outcomes other than "motivation to partner" (Kude et al., 2012) is not understood. Most importantly, to the best of our knowledge, no prior study has explicitly investigated the impacts of different resources on different types of innovation. This study

develops and tests six hypotheses on the direct and contingent effects of technological, commercial, and social capital on product and process innovation to address this gap. Figure 1 provides an overview of the hypotheses.

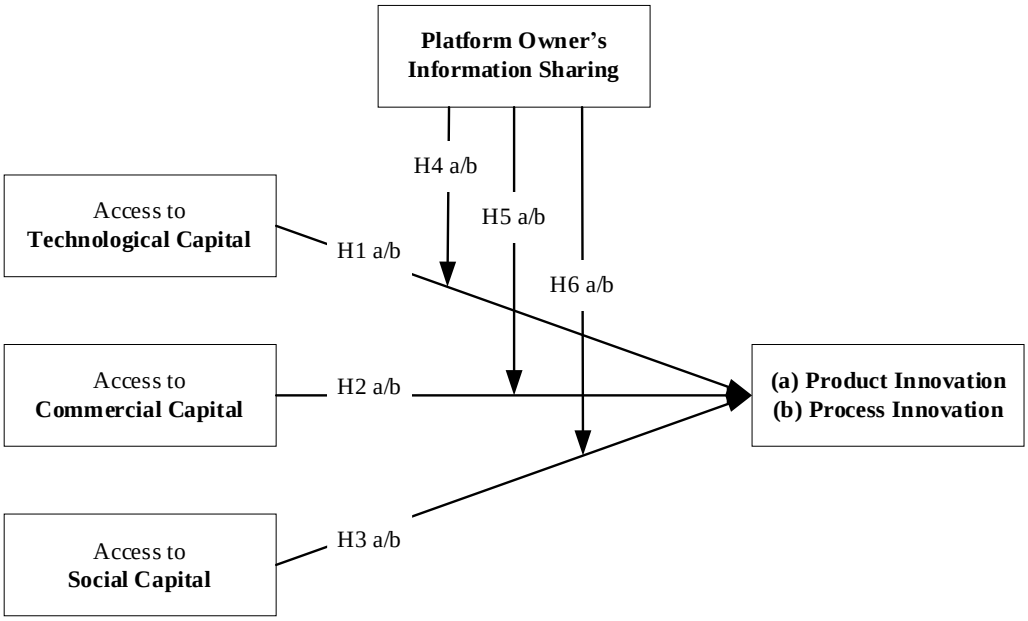

Figure 1: Hypotheses

Direct Effects

The technical resources offered by a platform owner to its ecosystem of complementors are designed for innovative reuse and recombination through 3rd-parties. (Eaton et al., 2015; Ghazawneh & Henfridsson, 2015; Wareham et al., 2014). These resources are made broadly and easily accessible through online partner portals (Foerderer et al., 2019; Huber et al., 2017) and standardized application programming interfaces (Baldwin & Clark, 2000). Complementors then combine these generic technological resources offered by the platform owner with their resources and capabilities in the process of value cocreation. However, because the resources and capabilities of complementors are often highly specific or even idiosyncratic (Ceccagnoli et al.,

2012; Foerderer et al., 2019; Huber et al., 2017; Kude et al., 2012), the mere presence of platform resources per se may not automatically translate into innovation. Instead, the complementor‘s ability to use and exploit these resources to create innovative products or services will hinge on the extent to which the standardized platform resources complement the complementor (Rochet & Tirole, 2003). For example, a complementor with specific enterprise software expertise is more likely to complement SAP's ERP platform with an innovative niche solution than a complementor with expertise in consumer software.

We also expect the technical resources offered by the platform owner to drive process innovation. Designed for extensibility and often sponsored by leading software companies such as Microsoft, Apple, Google, and SAP, digital platforms are often at the forefront of architectural innovations (Bozan et al., 2020). These architectural innovations spill over to the complementors development processes because using the platform requires embracing the architectural principles embedded in the platform. Therefore we hypothesize:

H1a: Stronger access to the platform owner’s technological capital is associated with higher product innovation.

H1b: Stronger access to the platform owner’s technological capital is associated with higher process innovation.

By providing commercial capital, platform owners enable complementors to address new and, therefore, a wider variety of markets. The more accessible this valuable commercial capital is to a particular complementor, the more diverse the customer base that the complementors can potentially serve. This will expose complementors to more varied customer needs, helping them innovate their products and services to address these needs. Moreover, having access to a broader and more varied customer base may force complementors into professionalizing their software

development and delivery processes. For example, higher levels of reliability and scalability will call for optimized development and delivery processes. Therefore, we hypothesize:

H2a: Stronger access to the platform owner's commercial capital is associated with higher product innovation.

H2a: Stronger access to the platform owner's commercial capital is associated with higher process innovation.

Platform owners are frequently industry and technology leaders and routinely enjoy high reputation levels (Huifang et al., 2019). Complementors can benefit from this reputation in various ways and to varying degrees. For example, they can undergo different levels of platform-specific certifications. Depending on their partner level, they can advertise their partnership with the platform owner to a lower or a higher degree. The more they can access and use the platform owner's social capital, the stronger the quality and reliability signals complementors can send to their customers. Thus, exploiting social capital will give complementors the confidence and latitude to take the risk of experimenting with creating novel product features or improving processes. Therefore, we hypothesize:

H3a: Stronger access to the platform owner's social capital is associated with higher product innovation.

H3b: Stronger access to the platform owner's social capital is associated with higher process innovation.

The Moderating Role of Platform Owner Information Sharing

Even though platform partnerships tend to be more hands-off or arm's length than other inter-organizational arrangements such as joint ventures or alliances (Tiwana et al., 2010), it is critical that the disparate resources of complementors and platform owners result in a coherent whole to

ensure platform owners and complementors co-create value for customers (Huber et al., 2017; Sarker et al., 2012). In other words, integration is needed to ensure the unification and synergistic combination of the complementors‘ resources and capabilities with the platform owner‘s technical, commercial, and social capital (Nevo & Wade, 2010). In platform ecosystems, the division of labor is such that complementors carry out and lead this integration effort (Sarker et al., 2012; Wareham et al., 2014). However, platform owners can facilitate this integration task if they frequently provide complementors with useful and valuable information (Sarker et al., 2012; Wareham et al., 2014). Past research suggests that sometimes platform owners are willing to go above and beyond their contractual obligations and provide complementors with exclusive and/or confidential knowledge (Foerderer et al., 2019; Huber et al., 2017; Hurni et al., 2022; Hurni et al., 2020). For example, platform owners can give complementors hints on how to better leverage existing APIs and inform them about upcoming platform features and interfaces, changes to their app store rules, and relevant certificates. In this way, complementors can better use the different resources made available by the platform owner. Therefore, we hypothesize:

H4a: The positive relationship between access to technological capital and product innovation is stronger when the platform owner shares more information with the complementor.

H4b: The positive relationship between access to technological capital and process innovation is stronger when the platform owner shares more information with the complementor.

H5a: The positive relationship between access to commercial capital and product innovation is stronger when the platform owner shares more information with the complementor.

H5b: The positive relationship between access to commercial capital and process innovation is stronger when the platform owner shares more information with the complementor.

H6a: The positive relationship between access to social capital and product innovation is stronger when the platform owner shares more information with the complementor.

H6b: The positive relationship between access to social capital and process innovation is stronger when the platform owner shares more information with the complementor.

METHODS

Data Collection

We tested our hypotheses through an online survey among complementors in platform ecosystems. Our sampling frame were companies that (1) operated in the software industry (software companies), (2) were part of at least one platform ecosystem, and (3) had activities in Switzerland. We focused on companies from Switzerland to reduce confounding effects, e.g., due to culture or legal norms.

To identify respondents, we relied on a commercial contact database, the contact databases of multiple industry associations in Switzerland, and the contact database of a leading Swiss IT consulting company. We matched these databases and screened each contact to verify that the company existed and operated in the software industry. From initially about 15,000 contacts, 4,955 hand-sorted contacts remained in the database. We deployed the survey in May 2015 using a commercial online survey tool (Qualtrics). Invitations for the survey were sent out by email to senior members of the companies. Six hundred thirty-two surveys were completed (12.75% response rate). To identify the complementors among these 632 companies, we asked whether they collaborated with a platform owner. For this purpose, we defined our understanding of a software platform: *"Under software partner, we understand legally independent companies which develop own software based on a software platform [e.g., an extension of SAP R/3], or configure an existing platform [e.g., parameterization of SAP ERP in customer projects], and are members of the partner program of the corresponding platform owner"*. Of the 632 companies, 196 indicated a relationship with a platform owner. These 196 companies were then asked questions about their relationship with their most important platform owner. We screened the responses of the 196 companies that indicated to be in a relationship with a platform owner using

the recommendations by Hair et al. (2006). We dropped 17 responses because they were either unengaged or showed missing values in more than 10% of the survey items or the dependent variables (Hair et al., 2006, p. 36). The data screening resulted in our final sample of 179 complete survey responses.

Error! Reference source not found. shows the distribution of complementors by the platform owner. By far, most complementors (76) indicated Microsoft as their platform owner, followed by Oracle (14), IBM (10), SAP (10), and Apple (10). As a free-text field in the survey indicated, the complementors that mentioned Microsoft as their most important platform owner contributed to Microsoft Dynamics, SharePoint, Azure,.Net, and Microsoft SQL. The descriptive statistics in Table 4 provide further insights into the composition of our sample.

Table 1: Distribution of complementors over platform owners

	Microsoft	Oracle	IBM	SAP	Apple	Other
No. of complementors with the most important platform owner	76	14	10	10	10	59

Instrument Development and Validation

We measured each construct through a block of questionnaire items. All items were measured on a five-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5). Table 3 shows the items. We used scales from prior literature (see the references in Table 3) to measure the platform owner's information sharing, product innovation, and process innovation. However, we adapted the scales to the context of platform ecosystems. Since we were not aware of survey research measuring technological capital, commercial capital, and social capital, we developed scales for these constructs based on the qualitative data and definitions provided in Kude et al. (2012). Our questionnaire also included several control variables to account for factors affecting our independent and dependent variables. The control variables are shown in Table 2.

Table 2: Control variables

Variable	*Measure*
Complementor Size	The count of full time employed equivalents in Switzerland (logarithmic transformation)
Export	1 if the complementor sells software or services outside Switzerland
Specific Industry	1 if the complementor addresses the requirements of a particular industry; 0 otherwise
Microsoft	1 if the most important platform owner was Microsoft; 0 otherwise
Multihoming	1 if the complementor complements platforms of more than one platform owner; 0 otherwise
Software Development Company	1 if the primary business purpose of a complementor was software development; 0 otherwise
Partnership Age	The number of years the complementor was in a partnership with the platform owner.
Layer Distance	The distance between the platform owner's and the complementor's layer level. The layer level is coded as 2 for the application software layer, 1 for the middleware layer, and 0 for the systems software layer.

To validate the questionnaire, we first invited three practitioners working for complementors and four senior IS scholars to review our constructs to assess and ensure content validity. We asked both the scholars and the practitioners to provide feedback and rate the extent to which each item captures each aspect of the construct domain (i.e., construct definition) using five-point Likert scales (Hinkin & Tracey, 1999). We refined our items based on the feedback obtained. We used the information gleaned from this construct review to refine our items. We then performed a pre-test among complementors from Austria and analyzed the scales through exploratory factor analysis. This led to further refinements of the items used for the final survey. Table 3 shows our final survey items.

Table 3: Survey Items

Construct (in parentheses: Cronbach's alpha, AVE)	Items (in parentheses: Outer loadings)	Source
Technological Capital (α=.83, AVE=.75)	Our partnership with <platform owner> … [TC1] … provides us with knowledge about the future development of its platform (.83). [TC2] … helps us to develop marketable software (.86). [TC3] … helps us to develop state-of-the-art software (.91).	Self-developed based on Kude et al. (2012)
Commercial Capital (α=.86, AVE=.78)	Our partnership with <platform owner> … [CC1] … gives us access to its attractive customer base (.90). [CC2] … supports us in our public relations network (e.g., marketing campaigns) (.88). [CC3] … helps us to increase our sales (.88).	Self-developed based on Kude et al. (2012)
Social Capital (α=.88, AVE=.81)	Our partnership with <platform owner> … [SC1] … signals to our customers that our products are of high quality (e.g., through certification) (.89). [SC2] … signals to our customers that our company is highly reliable (e.g., through a joint market presence) (.91). [SC3] … increases our reputation toward customers (.90).	Self-developed based on Kude et al. (2012)
Platform Owner's Information Sharing (α=.73, AVE=.65)	<Platform owner> provides us … [IS1] … with all information that may be useful to us (.80). [IS2] … regularly with information beyond of what is contractually mandated (.89). [IS3] … with confidential information (.71)	Adapted from Heide and John (1992); Heide and Miner (1992); Kaufmann and Dant (1992); Lusch and Brown (1996)
Product Innovation (α=.87, AVE=.72)	Our partnership with <platform owner> enabled us … [Prod1] … to develop radically new products (.76). [Prod2] … to give our customers unique advantages with our software <software> (.91). [Prod3] … to address new customers (.86). [Prod4] … to be the market leader in our segment (.88).	Adapted from Atuahene-Gima (1996)
Process Innovation (α=.87, AVE=.79)	Our partnership with <platform owner> enabled us … [Proc1] … to shorten innovation cycles (.90). [Proc2] … to reduce development costs (.87). [Proc3] … to continuously improvement our development processes (.90).	Adapted from Atuahene-Gima (1996)

After collecting the data for the final survey, we used confirmatory factor analysis procedures in SmartPLS to assess validity and reliability. Convergent validity and reliability were supported by Cronbach alpha values above.7, AVE values above.5, and outer loading above.7 for all constructs and items (see Table 3). Discriminant validity was supported by construct correlations below the AVE square roots for all construct pairs (Fornell & Larcker, 1981). Moreover, the differences between construct and cross-loadings were greater than.2 for all items, supporting discriminant validity.

Data Analysis

We tested our hypotheses using Ordinary Least Squares Regression. To reduce multicollinearity threats and easy interpretation, we standardized all continuous variables. Following a hierarchical regression approach, we first estimated baseline models with control variables only (model 1a for product innovation and 1b for process innovation). Then we estimated models with control variables and main effects (models 2a/2b) to test the main effects hypothesized in H1a/b, H2a/b, H3a/b. Then we added interaction effects (models 3a/3b) to test our interaction hypotheses H4a/b, H5a/b, and H6a/b). We verified that variance inflation factors were below 3.3, indicating no issues with multicollinearity. We also verified that the residuals followed a normal distribution, suggesting that the assumption of normally distributed error terms was met.

RESULTS

Table 4 shows descriptive statistics, Table 5 provides bivariate correlations, and

Table 6 shows the regression results.

Table 4: Descriptive Statistics

	Min	Max	Mean	Std. Dev
Product Innovation	1	5	3.45	0.92
Process Innovation	1	5	3.38	1.00
Complementor Size	.15	400	24.77	56.06
Export	0	1	.45	.499
Specific Industry	0	1	.26	.441
Multihoming	0	1	.51	.501
Software Development Company	0	1	.88	.323
Partnership Age	0	40	11.68	7.983
Layer Distance	0	2	.76	.870
Commercial Capital	1	5	3.31	1.05
Technical Capital	1	5	3.78	0.88
Social Capital	1	5	3.67	0.93
Information Exchange	1	5	3.00	0.86

Table 5: Bivariate correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) Product Innovation	1	.66	-.17	0	-.15	.02	.02	.14	.01	-.07	.46	.61	.45	.52
(2) Process Innovation	.66	1	-.19	-.1	-.12	0	-.03	.03	-.07	-.01	.4	.5	.31	.37
(3) Complementor Size	-.17	-.19	1	.09	.04	.04	.08	-.03	-.07	-.15	.03	-.04	-.02	-.1
(4) Export	0	-.1	.09	1	.1	-.04	0	.08	-.01	.05	.04	-.08	.09	-.03
(5) Specific Industry	-.15	-.12	.04	.1	1	.06	-.08	.06	-.09	.09	-.01	.01	-.04	-.14
(6) Microsoft	.02	0	.04	-.04	.06	1	.11	-.03	-.08	.08	-.03	.15	0	-.04
(7) Multihoming	.02	-.03	.08	0	-.08	.11	1	-.01	.1	-.05	.12	.04	.01	.01
(8) Software Development Company	.14	.03	-.03	.08	.06	-.03	-.01	1	.01	.1	.15	.14	.18	.06
(9) Partnership Age	.01	-.07	-.07	-.01	-.09	-.08	.1	.01	1	-.07	-.03	-.05	.02	-.01
(10) Layer Distance	-.07	-.01	-.15	.05	.09	.08	-.05	.1	-.07	1	-.18	.04	-.07	-.22
(11) Commercial Capital	.46	.4	.03	.04	-.01	-.03	.12	.15	-.03	-.18	1	.42	.57	.43
(12) Technical Capital	.61	.5	-.04	-.08	.01	.15	.04	.14	-.05	.04	.42	1	.58	.39
(13) Social Capital	.45	.31	-.02	.09	-.04	0	.01	.18	.02	-.07	.57	.58	1	.36
(14) Information Exchange	.52	.37	-.1	-.03	-.14	-.04	.01	.06	-.01	-.22	.43	.39	.36	1

Table 6: Regression Results

	Models 1a/b: Controls only		Models 2a/b: Controls and main effects		Models 3a/b: Controls, main effects, and interaction effetcs	
	a: Product Innovation	b: Process Innovation	a: Product Innovation	b: Process Innovation	a: Product Innovation	b: Process Innovation
Intercept	.00 (.31)	-.52 (.31)	.14 (.23)	.68 (.27)	.12 (.23)	.71 (.27)
Complementor size	-.14* (.06)	-.15* (.06)	-.10* (.04)	-.12* (.05)	-.08† (.04)	-.13* (.05)
Export	.04 (.15)	-.14 (.15)	.11 (.11)	-.08 (.13)	.13 (.11)	-.05 (.13)
Specific Industry	-.33† (.17)	-.26 (.17)	-.26* (.13)	-.23 (.14)	-.25* (.12)	-.24 (.14)
Microsoft	.09 (.16)	.02 (.16)	-.04 (.12)	-.08 (.13)	-.04 (.11)	-.11 (.13)
Multihoming	.04 (.15)	-.04 (.15)	-.03 (.11)	-.13 (.13)	-.08 (.11)	-.15 (.13)
Software Development Company	.47* (.23)	.13 (.23)	.13 (.17)	-.16 (.20)	.06 (.17)	-.22 (.20)
Partnership Age	.00 (.00)	-.01 (.01)	.00 (.00)	-.01 (.01)	.00 (.00)	-.01 (.01)
Layer Distance	-.12 (.09)	-.05 (.09)	-.02 (.07)	.03 (.08)	-.02 (.07)	.01 (.08)
Technological Capital			.46*** (.07)	.41*** (.08)	.48*** (.08)	.44*** (.09)
Commercial Capital			.17* (.07)	.26** (.08)	.18* (.07)	.28** (.08)
Social Capital			-.02 (.08)	-.10 (.09)	.03 (.08)	-.12 (.09)
Information Sharing			.24*** (.07)	.11 (.07)	.16* (.07)	.09 (.08)
Tech. Cap × Information Sharing					.04 (.07)	.08 (.08)
Com. Cap × Information Sharing					-.05 (.06)	.10 (.07)
Soc. Cap × Information Sharing					.19* (.08)	-.04 (.09)
ΔF	1.86†	.147	37.47***	20.00***	4.27**	1.41
R^2	.08	.07	.52	.37	.55	.39
Adj. R^2	.04	.02	.48	.32	.51	.33
(† p <.1, * p <.05, ** p <.01, *** p <.001, standard errors in parentheses, significant numbers in bold)						

In H1a/b through H3a/b, we hypothesized positive associations between access to different types of capital and product and process innovation. As models 2a/b show, access to technological capital had strong positive relationships with both product innovation (Model 2a, ß =.46, p<.001) and process innovation (Model 2b, ß =.41, p<.001), supporting H1a and H1b. Access to commercial capital was also significantly related with higher product innovation (Model 2a, ß

=.17, p<.05) and higher process innovation (Model 2b, ß =.26, p<.01), supporting H2a and H2b. Conversely, access to social capital was not significantly related to product innovation (Model 2a, ß =.-02, p>.1) or process innovation (Model 2b, ß =-.10, p>.1). The three types of capital and the platform owner's information sharing increased the explained variance from.08 (product innovation)/.07 (process innovation) to.52/.37, highlighting the high explanatory power of the four variables.

In H4a/b through H6a/b, we had hypothesized that the platform owner's information sharing strengthens the relationships between different types of capital and product and process innovation. As models 3a/b show, we did not find significant interaction effects for technological and product/process innovation and commercial capital and product/process innovation. However, the model shows that information sharing strengthened the relationship of social capital with product innovation (Model 3a, ß =.19, p<.05), though not with process innovation (Model 3a, ß =-.04, p>.1). Thus H6a is supported while H4a/b, H5a/b, and H6b are not supported. Figure 1 visualizes the significant interaction between social capital and the platform owner's information sharing on product innovation. As the solid line indicates, social capital had a slightly negative association with product innovation when the platform owner's information sharing was low (i.e., one standard deviation below the mean). Conversely, there was a strong positive association between social capital and product innovation under high information sharing.

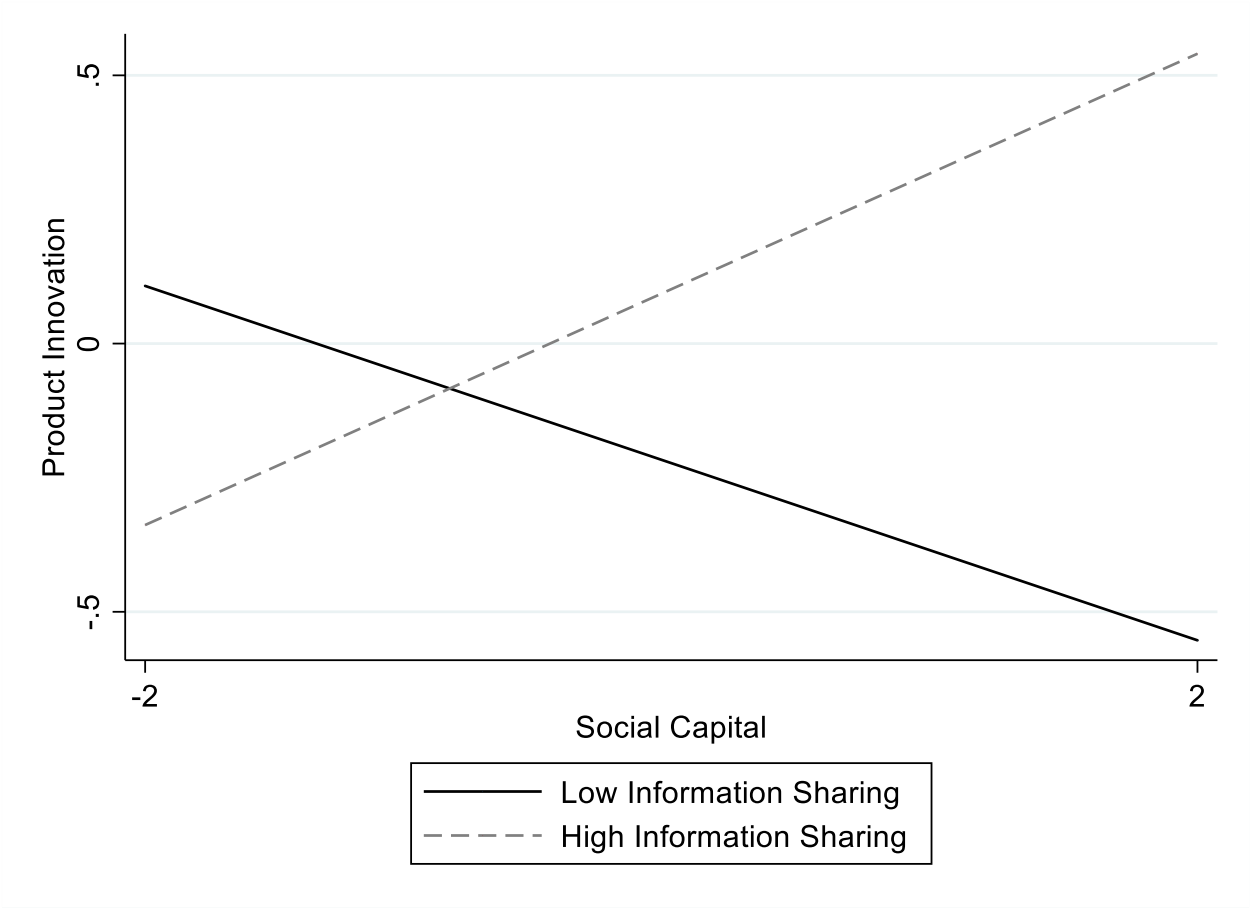

Figure 2: Interaction of Social Capital and Information Sharing

DISCUSSION AND IMPLICATIONS

The objective of this study was to theorize and test how the complementors' access to different types of resources offered by the platform owner (i.e., technological, commercial, and social) affects two distinct types of innovation: Product innovation and process innovation. Our results on 179 partnerships between complementors and platform owners support our first two hypotheses that complementors are more likely to create product and process innovations when they have strong access to the valuable technical (H1 a/b) and the commercial capital (H2 a/b) of the platform owner. At the same time, we did not find support for our third hypothesis (H3 a/b),

that stronger access to valuable social capital also leads to more product and process innovation. However, we found support for our hypothesis (H6a) that the platform owner's information sharing strengthens the relationships between the accessibility to social capital and product innovation. It is also notable that—other than expected—information sharing does not contribute to a stronger positive effect of technical and commercial capital access on complementor innovativeness. This suggests that innovation benefits are more difficult to achieve from access to social capital than technical and commercial capital. Specifically, social capital effects are more oriented toward influencing market reactions than directly affecting product and process innovations. However, if combined with access to exclusive information by the platform owner, complementors can use this information for enhancing products and, at the same time, use the social capital effects to attract customers with new product offerings. This points to the need for platform owners to go the extra mile to exploit their social capital and transfer its positive effects to its complementors through information sharing. Overall, our findings add to a better understanding of the sources of platform innovation. Specifically, they provide new insights into how to drive outside innovation in a platform ecosystem, specifically concerning the development of new or significantly improved software products or services (i.e., product innovations) or concerning new or significantly improved software development or delivery methods (i.e., process innovations).

Theoretical Contributions

Our results make several important contributions to theory. First, our study contributes to the literature on innovation in platform ecosystems by showing that access to valuable technical and commercial resources can lead to product and process innovation at the side of the complementors. In doing so, our study extends prior literature that has identified three types of resources of the platform owner, namely technical, commercial, and social capital, on the

provision of which it depends whether complementors join an ecosystem (Kude et al., 2012). However, joining a platform ecosystem is not enough to survive in the constant and continuously growing competition between ecosystems. Rather, it requires constant innovation and thus an increase in the attractiveness of the entire ecosystem vis-à-vis the customers. In this respect, platform ecosystems are characterized by their generativity, generally regarded as platform ecosystems' main promise (Evans et al., 2008; Iansiti & Levien, 2004). The idea behind generativity in platform ecosystems is that complementors can create surprising outside innovations by accessing complementary resources they could not have created themselves (Boudreau, 2012; Foerderer et al., 2018; Foerderer et al., 2019; Huber et al., 2017). In this regard, prior literature distinguishes between two types of (outside) innovation: Product and process innovation (Adner & Levinthal, 2001; Tarafdar & Gordon, 2007; Trantopoulos et al., 2017). Our study finds that the more accessible valuable technical and commercial resources, the more likely complementors create new software products or services or have considerably improved characteristics (i.e., product innovations), or significantly enhance software development or delivery method (i.e., process innovations). In that our study finds positive direct associations between the accessibility of valuable technical and commercial resources and both product and process innovations, it makes an important contribution to prior literature on outside innovation in and the generativity of platform ecosystems (Boudreau, 2010; Boudreau & Lakhani, 2009; Gawer & Cusumano, 2014).

Our study also supports the view that investigating into providing standard platform resources, i.e., boundary resources, pays off for platform owners (Hein et al., 2019). It leverages value-creation potential as a visibly enhanced product and process innovativeness at the complementor side.

Second, however, our study also points at the limitations of investing in generally applicable platform resources in the process of standardization toward achieving scalable infrastructures. Especially to benefit from less tangible platform resources, such as social capital, complementary investments into particular platform partnerships may be needed in the form of information sharing by the platform owner. Specifically, when it comes to product innovations, signaling effects of the platform owner's reputation are of limited use, if not accompanied with dyadic investments that help the complementor gain additional information about how to frame and position its new innovative product so that it appears as a synergistic complement to the platform, i.e., being aligned with the reputation of the platform owner.

Managerial Implications

Platform ecosystems are facing increasingly fierce competition from other platform ecosystems. To survive in this environment, platform owners must ensure that their platforms and surrounding ecosystems remain competitive. In this context, innovative processes and complements are key success factors. Our study provides three pieces of advice for nurturing such complement and process innovations in platform ecosystems. First, our study underscores the importance of platform owners making technological resources available and easily accessible to their complementors. Platform operators can take advantage of this insight by revisiting their support infrastructures to make their platform-specific technological resources accessible. Second, our study underscores the importance of platform owners making commercial resources available to their complementors. Platform operators can take advantage of this insight by providing their complementors access to commercial resources. Third, our study underscores the importance of platform owners providing social resources to their complementors, but only if they are willing to share vital information. Platform operators can take advantage of this insight by making their

partnership managers aware of the beneficial role of information sharing for enhancing product innovation of their complementors, with a special focus on allowing their complementors to benefit from the platform's social capital. This means that partnerships managers need to be aware of the platform's various sources of social capital (see, e.g., Nahapiet and Ghoshal (1998)) and how these can be brought to fruition in a particular partnership to enhance their partners' product innovations. For example, a platform owner may use its relational links to other complementors to bring together experts from different domains to infuse the innovation process.

Limitations and Future Research

This study is not without limitations. First, our cross-sectional research design inherently limits the study of causal relationships. Therefore, future studies should rely on longitudinal or experimental methods to capture the dynamic and complex interactions between the different resources. Second, our study included numerous firms from different ecosystems, but all from the same country. Therefore, under some circumstances, the cultural norms of that country may have biased our results. Therefore, future research should test the relationships examined in this study in other cultural or geographic settings. Third, we relied on data from a single source, making our study vulnerable to methodological bias. However, ex-post-tests did not reveal any such biases. Moreover, interaction effects, which are at the heart of our study, cannot be artifacts of common method biases (Siemsen et al., 2010).

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