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Risks of Digital Innovations: An Ecosystem Perspective

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Introduction

Digital technology is combining digital (e.g. software, mobile services) and physical (e.g. mobile phones, cars, sensors) components into new value propositions (Dahlander & Magnusson, 2008; Yoo, 2010; Yoo et al., 2010; Kolloch & Golker, 2016). Hence, to create and capture value through digital technology, firms can no longer solely rely on their own innovation efforts but are increasingly building ecosystems (Eaton et al., 2015). Tremendous success of firms like Google and Apple clearly demonstrates the crucial importance of such ecosystems. Accordingly, academic research on both strategy and business practice are currently paying increasing attention to this form of organizing innovations.

Such ecosystems consist of multi-directional relationships between diverse organizations and individuals with coevolving capabilities that depend on each other to create value. This perspective supersedes the traditional view of value chains based on dyadic supplier/buyer relationships (Iansiti & Levien, 2002; Moore, 1993). For instance, the innovation efforts of the focal firm and the third-party developers reciprocally influence each other making the relationships among the actors of the ecosystem central to its success (Eaton et al., 2011; Ghazawneh & Henfridsson, 2013).

Especially digital technologies possess a number of idiosyncratic features that make the development and deployment of ecosystems indispensable. In particular, the modularity (Baldwin & Clark, 2000; Langlois, 2002) of digital innovation is changing the traditional value chain into value networks (Garud & Kumaraswamy, 1993), and vertically integrated firms grow into networks of specialized firms (Langlois & Robertson, 1992). Consequently, the control over the single components as well as the product knowledge is increasingly distributed across various firms of different types (Yoo et al., 2010) which fundamentally reshapes the established logic of innovation (Lyytinen et al., 2016).

There are also more generic, not IT-related trends, which contribute to the growing importance of ecosystems. There are also more generic, not IT-related trends, which contribute to the growing importance of ecosystems. Organizations increasingly participate in ecosystems to capitalize on knowledge outside the boundaries of the single firm (Andersson et al., 2008; Cohen & Levinthal,

1990) and achieve collaborative advantage (Huxham & Vangen, 2005). Opening up the boundaries of innovation processes to the ecosystem enables firms to draw on additional resources and to share them with external actors, which leads to new opportunities to design novel business models (Boudreau, 2012; Zott et al., 2011).

In sum, from the perspective of organizing digital ecosystems are characterized by the following fundamental characteristic: To create and capture value through ecosystems, companies have to accept mutual interdependence and learn to deal with it in an effective and efficient way. The accelerating interdependence on ecosystem partners, however, has not only created new business opportunities but also introduced essential new risks. These risks are at the center of our paper.

Past research on strategic management has extensively explored generic, non-technology related risks associated with inter-firm collaboration. In this research stream, risk is conceptually linked to corporate strategic objectives and is seen as “negative outcome variance” (Das & Teng, 1996: 829). In particular, Das & Teng (1996, 1999 & 2001) divide the risks of strategic alliances within two broad categories – relational and performance risk. While relational risk is focusing on “the probability and consequence of not having satisfactory cooperation” (Das & Teng, 2001: 253), performance risk is related to every risk that might affect the alliance apart from successful cooperation within a dyadic partnership. This research on risks in inter-firm alliances and other collaborative forms of organizing, however, did not consider a number of crucial facets particularly related to innovative digital ecosystems developed in the 2000s.

First, even those organizational scholars who explicitly considered not only the synergy argument in terms of the “collaborative advantage” but also the risk of “collaborative inertia” (e.g. Huxham & Vangen, 2005) have explored the particular facet of innovation only marginally. Collaboration on innovation, however, significantly differs from other forms of strategic alliances both in quantitative and qualitative terms: As it deals with technological and market insecurity, it bears higher and more diverse risks than routine collaboration.

Second, specifically digital innovations seriously differ from other kinds of innovations and thus cause new risks for actors. As indicated above, particularly the generativity of digital technology as well as of the evolving ecosystem (Tiwana et al., 2010; Zittrain, 2006) creates several risks. For instance, the firm that sets up platforms has to balance between the generativity of third-party developers (Sanchez & Mahoney, 1996) and the architectural control of the product design and its evolution, which can lead to serious unintended consequences. This challenge exceeds the traditional requirements of innovations to integrate heterogeneous knowledge elements (Nonaka, 1994) and thus creates new dynamics and complexity within digital ecosystems (Hanseth & Lyytinen, 2010; Selander et al., 2013).

Third, both from the theoretical and empirical perspective, past research on risk has been mainly focusing on dyadic forms of organizing, such as strategic alliances (e.g., Das & Teng, 1996) neglecting the interdependence between exchange partners in the pursuit of joint value and risk (Zajac & Olson, 1993). The characteristics of emerging digital ecosystems, however, fundamentally differ from dyadic partnerships: As mentioned above, these ecosystems are characterized by mutual interdependence of many interconnected and multi-level embedded actors. Accordingly, we argue that the network approach (e.g. Gulati et al., 2000) can provide novel and useful insights into the functioning of digital technology in general and the risks in these ecosystems in particular. In line with Granovetter's (1992: 33) fundamental argument, we argue that this network aspect "is especially crucial to keep in mind because it is easy to slip into 'dyadic atomization', a type of reductionism."

On the other hand, as past research on strategic alliances built on fundamental theories of organizing, such as transaction cost theory (Williamson, 1975, 1985 & 1991), it was able to deliver deep insights on various facets of inter-firm collaboration. While some scholars criticize that current research on digital ecosystems still lacks a solid theoretical foundation (Yoo et al., 2012), we argue that previous studies can offer a valuable platform especially for the analysis of risks associated with those ecosystems. Hence, we build particularly on the seminal work of Das & Teng (1996, 1999 & 2001) on risks in strategic alliances and enrich this fruitful foundation by considering specific characteristics of digital ecosystems, multiple forms of interfirm dependencies (e.g. Adner & Kapoor, 2010; Staudenmayer et al., 2005; Pfeffer & Salancik, 1978; Thompson, 1967), and the network instead of purely dyadic perspective (Gulati et al., 2000; Carpenter et al., 2012). Hereby, we provide a conceptual model of the risks of digital ecosystems by focusing on strategic risks for firms participating in an ecosystem.

In what follows, we first discuss the concepts of risks and uncertainty and their application in the investigation of ecosystems. Second, we review previous work on risks related to interorganizational exchange and argue that special features of digital technology as both operant resource and sense making resource (Nambisan, 2013; Lyytinen et al., 2016) have to be considered. Third, we analyze key features of digital innovation and ecosystems, such as generativity and interdependence that not only lead to new benefits but also cause new risks, and give a detailed explanation of how they shape risk perception of managers. Fourth, drawing on these research streams we suggest a comprehensive framework for strategic risk analysis in digital ecosystems. In doing so, we also enrich the theoretical understanding of risks in ecosystems by explicitly considering various forms of interdependence and the inter-firm network as a promising form of organizing for digital innovations.

The Concept of Risk

Although the concept of risk is a key factor in strategic decision making, its definition remains controversial. The classical decision making theory most commonly defines it as the variation in the distribution of possible outcomes, their likelihoods of occurrence, and their subjective values (Arrow, 1965). Thus, an alternative is conceived risky if the variance of outcome is large in both ways, the negative as well as the positive one (March & Shapira, 1987).

Organizational researchers have frequently claimed, however, that this conceptualization is mostly divergent with the way of how managers perceive risk (March, 1981) and how risk in decision making influences managerial behavior (Vlek & Stallen 1980; Slovic et al., 1982). In fact, managers see risk in a quite different way as they do not address the uncertainty about positive variance in outcomes explicitly as an important aspect of risk (MacCrimmon & Wehrung 1986). Furthermore and most importantly, as risk in managerial decision-making is "an inherently subjective construct" (Yates & Stone, 1992: 5), the subjective interpretation of the components of cost and risk (Kahneman & Tversky 1982; Weber & Milliman, 1997) has to be acknowledged. Finally, the difference between risk and uncertainty is important: According to Kaplan & Garrick (1981), the concept of risk involves both uncertainty and some kind of loss or damage experienced by a manager.

As manifold as the different understandings of the term risk are the typologies of its concept (e.g. Schwer & Yucelt, 1984; Miller, 1992). In what follows we build on the trichotomy of Kaplan and Mikes (2012) that distinguishes between preventable, external and strategy risk. While the first category is related to internal and operational risks (e.g. breakdowns in routine operational processes) that do not generate any strategic benefits and hence should be avoided, external risk comprises uncontrollable hazards caused by extraorganizational sources (e.g. terrorism, natural disasters, financial crisis).

The last category, strategy risks, is directly related to business objectives: Firms are inherently willing to take these risks in anticipation of higher return to sustain competitive advantage (Baird & Thomas, 1985). As strategic actions that are taken for superior returns (e.g. R &D projects and innovation) are always risky, managers have to reduce the likelihood and the impact of strategic risks in a cost-effective manner (Kaplan & Mikes, 2012).

A Strategic Approach to Risks of Digital Ecosystems

Applying the relational view of competitive advantage (Dyer & Singh, 1998) companies can create relational rents when entering partnerships with other firms that provide complementary resources. Thus, the decision to participate in a digital ecosystem is always a strategic one (Moore, 1993). In line with the differentiation presented above we focus on strategic risks that are within the boundaries of the given ecosystem neglecting the operational risks (e.g. technical system failure, project risks) and the risks of the global environment (e.g. earthquakes, terrorism, etc.). Accordingly, for the purpose of this study we define the risks of digital ecosystems as a function of uncertainty and loss that are related to the strategic decision to participate in the given ecosystem and perceived by the decision maker. In the following, we will refine the concept of risk by classifying it into different categories that are particularly relevant for digital ecosystems.

Previous Work on Risks in Interorganizational Arrangements

Past research on strategic management in interorganizational exchange considers a world in which managers choose governance structures in accordance with a subjective interpretation of the respective transaction costs (Chiles & McMackin, 1996). Literature on the risks of such alliances has extensively explored generic, non-technology related risks associated with inter-firm exchange. In particular, Das & Teng (1996, 1999 & 2001) divide the risks of strategic alliances into two broad categories – relational and performance risk. The latter one is related to market and capability factors that may disturb the cooperation. In every strategic choice, it is possible that the success of this action does not solely rely on the efforts and control of a firm (Ring & Van de Ven, 1994). Thus, performance risk is defined as all other risks apart from that directly related to the cooperation itself that might hamper the success of the alliance (e.g. intensified rivalry, regulatory changes, lack of competence) (Das & Teng, 1996; Tyler & Steensma, 1998). For instance, despite a desire to cooperate, firms might not be able to do so due to a lack of competence (Lam, 1997). This type of risk is part of every strategic organizational action and not specifically bound to interorganizational exchange (Das & Teng, 2001). Accordingly, alliances frequently aim at reducing such performance risk (Pisano, 1991; Hagedoorn, 1993).

On the contrary, relational risk is an inherent part interfirm cooperation. This category of risk is concerned with “the probability and consequence of not having satisfactory cooperation” (Das & Teng, 2001: 253). Relational risks arise from the possibility that partners are not exclusively focusing on the optimization of the alliance´s joint objective but on their opportunistic self-interest (e.g. Das & Teng, 1996; Nooteboom et al., 1997; Kale et al., 2000). In emphasizing relational risks, past research essentially built on the transaction cost economics (TCE) (Williamson, 1975, 1985). As one idiosyncrasy of interorganizational arrangements is related to the cooperation with a partner, opposing goals and self-interest of each individual party create uncertainty in the behavior of the counterpart (Ouchi, 1980). This uncertainty can destabilize an alliance due to the possible opportunistic behavior of the partner (Parkhe, 1993) and multiply the rates of failure (Bleeke & Ernst, 1991).

The Gaps in Analyzing Risks of Digital Ecosystems

Past research on strategic alliances was able to deliver deep insights on both relational and strategic risks (Das & Teng, 1996). However, this perspective reveals its inherent limitations when confronted with the main features of today’s digital ecosystems. First, ecosystems consist of multi-directional relationships between organizations as well as individuals with coevolving capabilities and high level of dependence on each other. These characteristics supersede the traditional view of innovation value chains based on dyadic relationships (Iansiti & Levien, 2002; Walley, 2007) as today’s firms are increasingly embedded in networks of multi-level interdependencies (Adner & Kapoor, 2010; Boland et al., 2007; Schilling & Phelps, 2007) for the co-creation of value.

Second, the success of a firm is no longer limited to its own effort or the success of a dyadic alliance but on the interplay and prosperity of the whole system to create mutual value for its members. Thus, the sustainability (Iansiti & Levien, 2002) and the performance (Gulati et al., 2000) of the total ecosystem are important for the success of each individual member.

Third, past research has viewed digital technology as a black box (Akhlaghpour et al., 2013) or as operand resource (Nambisan, 2013; Fichman et al., 2014; Lusch & Nambisan, 2015). However, this view is limited as digital technology inherently influences the structure and process of innovation (Yoo et al., 2012; Lyytinen et al., 2016). Consider, for instance, software-based platforms (Tiwana et al., 2010), crowdsourcing-based business models (Kohler, 2015) or the importance of product complementarity for ecosystem success (Gao & Iyer, 2006) which generate a variety of innovations on an unprecedented scale (Boudreau 2012; Yoo et al. 2010).

Hence, we argue that these aspects have to be taken into consideration for developing an integrated perspective on the risks of digital ecosystems. In the following, we address these gaps by explaining how the new contingencies of a digital technology and the corresponding ecosystem shape the totality of risk firms encounter when participating in such networks.

An Ecosystem Perspective on Risk

As past research on risks in strategic alliances was able to deliver deep insights on various facets of inter-firm collaboration, we propose that the categories, performance risk and relational risk are substantial part of an integrated model for analysing the risks of digital ecosystems. For the purpose of our research, we define digital ecosystems as a network of heterogeneous actors around a digital platform, i.e. an extensible software code base. We therefore apply a network perspective (e.g. Jarillo, 1988; Gulati & Singh, 1998; Gulati et al., 2000), recognizing the importance of network embeddedness (Granovetter, 1985) and the interdependence among the network participants, grounded in mutual co-specialization (Adner & Kapoor, 2010).

The embeddedness in networks of social, professional, and exchange relationships with other organizational actors (Gulati et al., 2000) outlined the importance of both relational (e.g. Tiwana, 2008) and structural (e.g. Afuah, 2000) properties for a firm’s performance.

Within ecosystems, multilevel embeddedness is especially prevalent as actors are not atomistic but embedded in a network of horizontal and vertical relationships with other organizations like suppliers, customers or competitors, including relationships across industry and national boarders, to create mutual value for the whole ecosystem and its individual members (e.g. Gulati, 1998; Iansiti & Levien, 2002). Network embeddedness can provide a firm with access to information, resources, markets, and technologies or allow achieving strategic goals (Gulati et al., 2000). However, it may also create risks for firms within ecosystems. Accordingly, the network perspective is a suitable lens to expand the dyadic perspective on risk to digital ecosystems and considering the multilevel embeddedness and its influence on risk.

Relational Risk

As mentioned above, the rationale behind relational risk is the behavioral assumption of opportunistic behavior that leads to conflicts if the partner is focusing on individual at the expense of shared goals (Khanna et al., 1998; Das & Rahman, 2010). Interorganizational collaboration is always a tradeoff between the advantages generated through combining complementary resources and the threat of opportunism (Dyer, 1997). Nevertheless, the costs of opportunistic behavior within an interorganizational network are much higher because hazards to the reputation of a single firm can affect not just the specific dyadic alliance in which the firm behaved opportunistically, but also the whole network (Gulati et al., 2000). Specific investments in ecosystem relationships can lead to lock in and consequently increase the threat of opportunistic behavior (Williamson, 1985), especially if platform leaders exploit their self-interests at complementors' cost (Kude & Dibbern, 2009).

Another crucial factor that shapes the relational risk in digital ecosystems is the power imbalance in hub and niche player relationships. The platform leader can utilize its dominant position in the relationships to behave opportunistically.

Furthermore, relational risk may result from a hidden agenda of the partner who might for instance capture resources (e.g. knowledge, technology) that are part of core competence of the firm to use it for individual interests or the not intended use of technology (Hagedoorn, 1993; Inkpen, 1998; Das & Teng, 2001). Hence, alliance partners may arise to competitors (Gomes-Casseres, 1996; Yoshino & Rangan, 1995). This spillover of knowledge is especially significant in ecosystems shaped by coopetition, i.e. simultaneous cooperation and competition between firms (Nalebuff & Brandenburger, 1997; Afuah, 2000). Thus, we assume:

Proposition 1: *Relational risk is more prevalent in digital ecosystems, as the consequences of opportunistic behavior are more severe and may affect the whole ecosystem.*

Performance Risk

For the purpose of our paper, we refer to the concept of performance risk (Das & Teng, 1996) as the inability to cooperate because of the lack of competences. In other words, while relational risks refer to the "will" dimension, performance risks are associated with the skill dimension. In ecosystems, organizations are generally assumed to build partnerships in order to obtain access to other firm's capabilities and resources (Teece et al., 1997), especially if firms are not able to create them on their own in a feasible way. However, for a firm participating in an ecosystem it can also be strategically constraining as it may lock firms in ineffective relations or prevent partnerships with attractive firms outside the specific ecosystem (Håkansson & Ford, 2002; Gulati et al., 2000).

Several authors noted the interdependencies of firms in complementary markets (Katz & Shapiro, 1986; Henderson & Clark, 1990) and the role of coevolution of the partners´ capabilities. In particular, competitive advantage in ecosystems relies on tacit resources like those of dynamic capabilities shared in collaborative relations (Moore, 1996; Afuah, 2000). The coevolution of capabilities increases the dependence between single firms. Hence, this demonstrates the need to view resources as residing in a network and not solely within the boundaries of a single firm or a dyadic alliance. As firms and capabilities coevolve, strategic changes, decisions or failure of one company may strongly affect other companies within ecosystem. Firms become dependent not just on skills and performance of the dyadic alliance partner, but also on indirect connections within the network since the effectiveness of the partners in managing their relationships with third parties may directly influence the alliance (Snehota & Håkansson, 1989) and vice versa lead to insulating effects from knowledge that lies beyond the network (Uzzi, 1996 & 1997). Thus, we assume:

Proposition 2: *The specific characteristics of digital ecosystem foster the risk of an unsuccessful interorganizational relationship due to a lack of capabilities, i.e. performance risk.*

Ecosystem Characteristics Risk

While external risk that is uncontrollable and not related to the strategic perspective on interorganizational networks is not covered in our framework, the sustainability and the success of the whole ecosystem is a crucial factor when analyzing the risks of digital ecosystems. In other words, risk analysis on the network level gains in importance. As business networks and ecosystems are dynamic and steadily evolving (e.g. Iansiti & Levien, 2002; Gulati et al., 2000), single firms in such networks are increasingly exposed to strategic vulnerability and complexity of managing multi-organizational exchange (Krapfel et al., 1991). Characteristics of an ecosystem like the openness of boundaries substantially increase interdependency among actors (Albert et al., 2015). As we discussed in the previous section, firms are dependent on the performance and capabilities of their partners. However, the dependence in ecosystems makes the performance and sustainability of the whole network crucial for the success of each individual firm within. If the whole ecosystem is not able to reach its system level goals, this is directly affecting every individual firm within the network (Puranam et al., 2014).

Furthermore, the stability of such interorganizational arrangements is crucial for the robustness of a system (Carley, 1991). Negative aspects of the multilevel embeddedness in ecosystems are the increased vulnerability to external shocks (Uzzi, 1996 & 1997). These shocks influence the success of both, the whole network as well as the single firm.

Several authors attempted to explain the sustainability of ecosystems by concepts of ecosystem "health" (e.g. Iansiti & Levien, 2002; Den Hartigh et al., 2012; Manikas & Hansen, 2013) in terms of the capability of an ecosystem to face and survive disruptions, the efficiency with which an ecosystem creates innovation and the capacity to create novel and diverse capabilities. Although the conceptualization of the health of ecosystem remains controversial, this discussion illustrates the importance of the sustainability of an ecosystem to create mutual value and vice versa, the risk for each individual firm if it is not able to reach the system goals. Accordingly, we suggest:

Proposition 3a: *The ecosystem not being healthy and the failure to reach its system level goals constitute risks for digital ecosystems and each firm within.*

As an ecosystem consists of a set of value creation and distribution relationships among interdependent actors, a further important and underexplored category of ecosystem risks is related to the network characteristics. In these terms, the concept of relational and strategic risks can be brought into connection with the differentiation between relational and structural embeddedness. As mentioned by Granovetter (1992), the idea of social embeddedness refers to the fact that economic action and outcomes are affected not only by the actors' dyadic relations but also by the overall network structure. As relational embeddedness describes characteristics of particular dyadic relationships, such as trust and reciprocity (Nahapiet & Ghoshal, 1998), we first assume that the arm’s-length ties within the ecosystem bear much higher relational risks than embedded ties since the latter “shift the logic of opportunism to a logic of trustful cooperative behavior” (Uzzi & Lancaster, 2003: 384).

Second, as structural embeddedness describes the properties of the network of relations as a whole, such as network configuration (Nahapiet & Ghoshal, 1998), we argue that essential risks are associated also with the position of the given actor in the ecosystem’s internal network. Past research has revealed, for instance, that structural position of a broker that spans structural holes confers a number of benefits, such as information and control benefits (Burt, 2000, 2009). At the other hand, however, this structural position builds not only the condition for knowledge transfer and learning, but for opportunistic behavior as well as the broker can use information asymmetries for “strategic behavior” (Williamson, 1993). In other words, being connected to a broker creates for the peripheral actors the risk of being manipulated: The “tertius gaudens” is able to negotiate for favorable terms (Burt, 2009), but at the expense of his contacts.

In addition to these risks of the broker’s network contacts, past research also indicates that the advantageous brokerage position bear risks for the broker himself – in the case when the broker’s contacts possess very specific, unique resources and competences. Although firms can benefit from the exclusive resources brought in by non-substitutable alliance partners, empirical studies show that the costs of allying with such partners could offset those benefits (Bae & Gargiulo, 2004). In other words, brokers between disconnected partners gain benefits from their structural position, but those benefits decrease as the proportion of non-substitutable partners in the brokers’ alliance networks and thus, their dependence from those network partners increases (Bae & Gargiulo, 2004). In sum, we assume:

Proposition 3b: *Structural position of the given firm in the ecosystem's value creation and distribution network does not only create advantages but also bears essential risks as it might create strategic dependencies, increase costs of maintaining strategically important relationships and weaken the bargaining position.*

Digital Technology Risk

Recent research on information systems emphasizes the shift from the traditional perspective on the influences of IT on processes and structures within organizations (e.g. Zammuto et al., 2007) to a focus on the transformative aspects of digital technology and the emergence of novel organizing logics (e.g. Sambamurthy & Zmud, 2000; Yoo et al., 2012; Lyytinen et al., 2016). Digital technologies, like platforms, constitute operant resources (Nambisan, 2013; Lusch & Nambisan, 2015) and produce a variety of innovation outcome on an unprecedented scale (Boudreau 2012; Yoo et al. 2010). Hence, we argue, that the role of digital technology is a substantial element constituting for risk in interorganizational networks. For our integrated framework, we relate to three characteristics of digital technology as influencing the risk of digital ecosystems: modularity; convergence; and generativity.

First, the separation of device and service as well as between network and content results in a layered modular architecture of digital technology (Adomavicius et al., 2008; Gao & Iyer, 2006) offering the possibility to couple previously separated components into novel value propositions (Yoo et al., 2010). This tendency towards a disintegrated architecture is mirrored by an increasing degree of interorganizational modularity (Baldwin, 2008; Henfridsson et al., 2014). In layered modularity, the architecture is not predefined a priori by a focal firm, but emerging through highly uncoordinated interaction of heterogeneous third-party developers that build on top of a platform (Tiwana et al., 2010). Consequently, the absence of design rules accelerates complexity of innovation and hence the risk of failure for a single firm or even the whole ecosystem (Yoo et al., 2010). Moreover, modularity increases interorganizational dependencies (Dyer & Singh, 1998). For instance, complementors are highly dependent on the platform owner providing application programming interfaces (API) or sharing resources to enable complementors to participate in the creation of value (Tiwana et al., 2010). Technological dependency one the one hand can lead to lock-in effects (Tiwana et al., 2010; Katz & Shapiro, 1986) on the platform and hence significantly increases switching costs to another technology amplifying the imbalance of power between partners. On the other hand, the dependence on access to knowledge and resources increases the need for investment in relation specific assets and makes it possible to keep actors out of the ecosystem. Consequently, we suggest:

Proposition 4a: *The layered modular architecture of digital innovation accelerates strategic risk a firm is facing due to technological interdependency.*

Second, the properties of digital innovation build a foundation for open and flexible affordances that is, "an action potential" that describes "what an individual or organization with a particular purpose can do with a technology or information system" (Majchrzak & Markus, 2012). These affordances of digital technology determine two unique characteristics of organizational innovation created by this technology – convergence and generativity (Yoo et al., 2010). Convergence brings together previously separated user experiences (e.g. adding mobile internet), physical and digital components (e.g. smart products) and previously separated industries (e.g. software and hardware industry) (Yoo et al., 2012). Digitally enabled convergence creates new links between previously unconnected knowledge and actors accelerating the heterogeneity of knowledge, tools for innovation as well as the community of actors that contribute to the creation of value (Lyytinen et al., 2016). The diversity of business models, corporate identities and cultures, business practices as well as technologies among the firms within the strategic network is significantly increasing complexity (Hanseth & Lyytinen, 2010). This growth in complexity constitutes additional risk of failure in managing interorganizational innovation. Furthermore, the heterogeneity of cultures (e.g. hardware and software industry) and diversity in network participants increases the risk of conflicts between firms during the political mechanism that innovation requires (Boland et al., 2007). "Social translation", i.e. the transformation of the social system of the actors within the ecosystem (Lyytinen et al., 2016), is frequently filled with conflicts as heterogeneity grows. We argue that convergence is enhancing the firms' investment to cross cognitive distance (Nooteboom, 1992) and the requirements for the firms´ absorptive capacity to do so (Cohen & Levinthal, 1990) as the semantic distance and ambiguity between knowledge elements grows and challenges what Lyytinen et al. (2016) call "cognitive translation". We therefore propose:

Proposition 4b: *Digital convergence leads to increase requirements for managing heterogeneity in cognitive as well as social translation and thus fosters the risk of digital ecosystems.*

Third, as digital innovation combines different layers at the same time in often unexpected ways (Adomavicius et al., 2008; Benkler, 2006), generativity reflects the dynamics and often unpredictable and unintended outcome of this specific kind of innovation (Yoo et al. 2010; Zittrain, 2006). In other words, generativity refers to the “reproductive capacity” of an ecosystem “to produce unprompted and uncoordinated changes in its structure and behavior without the control of a central authority” (Um et al., 2013: 4). While past studies see generativity as a positive driver of digital innovation, it can also lead to negative outcomes. When platforms become too disperse and fragmented, they are less attractive for both customers and partners. This reduces the value for each individual member of the ecosystem (Katz & Shapiro, 1994) leading to a paradox between the different logics of hierarchical control and decentralized generativity. For instance, if the distribution of power and control grows it increases uncertainty, as too many actors can make critical decisions concerning the innovation (Eaton et al., 2011). Vice versa, platform owners must exercise a certain amount of economic, social and technological control to ensure the creation of value for the ecosystem (Tiwana et al., 2010) inducing platform owners to move towards stricter control (Sarker et al. 2012). A lack of control, especially when complexity and interdependence are high, is likely to increase the perceived risk in interorganizational exchange (Das & Teng, 1996 & 2001; Dyer & Singh, 1998). This leads to the following proposition:

Proposition 4c: *Generativity multiplies the uncertainty of outcome within digital ecosystems and the probability of loss increasing strategic risks.*

An Integrated Framework for Analysing Risks in Digital Ecosystems

As previous research mentioned, there is a need for an integrated perspective on the totality of risk the firms have to take into account when making decisions (e.g. Brouthers, 1995; Das & Teng, 1996). Hence, we provide an integrated framework of the risks firms face when operating in digital ecosystems (see Figure 1). Our theoretical framework of risks of digital ecosystems consists of four specific types of risk arising under the antecedents of multi-level embeddedness (Gulati & Singh, 1998; Gulati, et al., 2000).

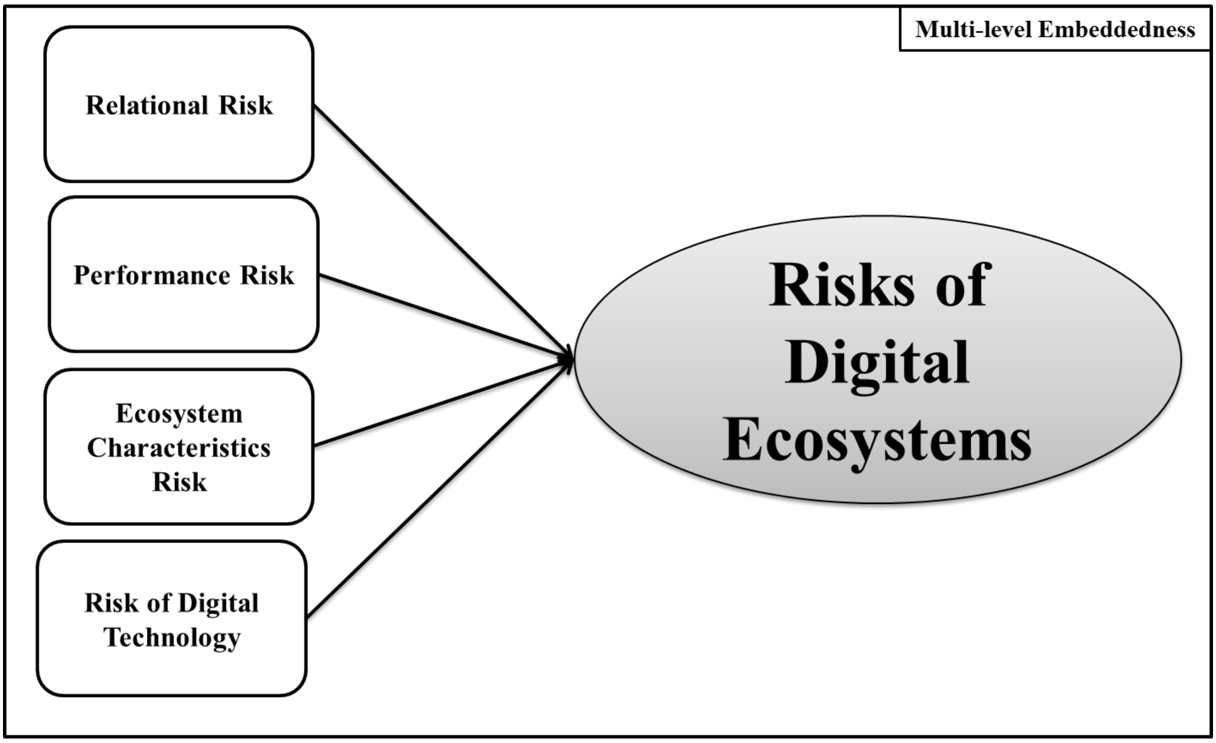

Figure 1 Theoretical Framework for the Risks of Digital Ecosystems

First, relational risk is covering the risk of partners' opportunistic behavior, which increases through coopetition, the imbalance of power and the embeddedness into the ecosystem.

Second, performance risk is grounded in the partners' lack of competence. This risk is accelerated by the need for dynamic capabilities to manage coevolution of partners within the ecosystem as well as interdependence and embeddedness that can cause indirect affection of performance risk, i.e. third-party lack of capability.

Third, the ecosystem characteristics risk is associated with the failure of the whole ecosystem to reach the system goal and create value for its members.

Fourth, digital technology risk is of threefold nature. The layered modular architecture of digital innovation accelerates the risk a firm is facing due to technological interdependency and consecutive lock-in effect that increases switching costs. Digital convergence accumulates the requirements for managing heterogeneity in cognitive as well as social translation. In addition, generativity multiplies the uncertainty of outcome within digital ecosystems and the probability of loss related to it.

Although we have treated the four categories of risks of digital ecosystems separately for analytic purposes, we assume that they are interrelated to some extent. For instance, interdependence is a crucial antecedent for risk in all categories.

Conclusion

Our primary objective in this paper is to provide an integrated framework for the strategic risks of digital ecosystems that threat participating firms. We argue that expanding previous research on interorganizational alliances to the idiosyncrasies of ecosystems (e.g. Iansiti & Levien, 2002) and integrating the role of digital technology as operant resource (e.g. Nambisan & Lusch, 2015) leads to a more comprehensive view of the strategic risks the firms face. Traditionally, strategy research has considered technology as an operand resource and was limited to a dyadic perspective on interorganizational alliances.

Our conceptual study draws on the seminal concepts of transaction cost economics (e.g. Williamson, 1985 & 1991) and strategic network embeddedness (e.g. Granovetter, 1985; Gulati et al., 2000). Hence, our research contributes to previous work on the risks of interorganizational arrangements (e.g. Das & Teng, 1996 &2001) and recent studies on the role of digital innovation on strategic management as well as interorganizational collaboration (e.g. Yoo et al., 2012; Lyytinen et al., 2016).

As we suggested earlier, empirical research is required to provide evidence of three main concerns. First, we highlighted the inherently subjective nature of risk and that the perception of what actually constitutes a hazard and how it will influence the firm might vary between different decision makers. Second, empirical research should differentiate between distinct clusters of ecosystem participants, as different roles (e.g. niche player; platform owner) will emphasize different risks. Third, further examination should shed light on the question on how different types of ecosystems (e.g. mobile, EAS, open source etc.) and different governance modes within such, shape risk in digital ecosystems.

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