THE ANTECEDENTS AND CONSEQUENCES OF MULTI-FIRM TECHNOLOGY COORDINATION: AN ECOSYSTEM PERSPECTIVE

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Abstract

Multiparty technology coordination bodies that bring together hundreds of firms to define the technical rules of interaction between components in a product-system, are an increasingly influential organizational arrangement, as exemplified by the market success of technology standards such as WiFi, Bluetooth and HDMI. Yet we are limited in our understanding of the antecedents to such coordination, and, conditional on formation of a coordination structure, the factors that enableits success. We propose a conceptual framework that integrates research on alliances, coopetition, and ecosystems, and builds on the tension between value creation and value capture that is specific to the multilateral technology coordination context. Our two-part framework first proposes that the impetus to create value using multifirm coordination forums is spurred by the modular structure of the ecosystem, the distribution of firms' knowledge and competitive positions within this structure, andthe extent to which potential complementarities from coordination are multilateral. We then suggest that the effectiveness of the decisions that emerge from these forums may ultimately be constrained by asymmetries across participating firms, both in terms of theirpotential for future value capture and theiradjustment costs of existing resources and capabilities as a consequence of the proposed rules.

Keywords: Ecosystems, alliances, technological change, standards, coopetition, coordination

Introduction

Large-scale multi-firm technology forums that develop and promote coordinated technology standards are now foundational to almost every technology-driven industry. Recent estimates place over five hundred such distinct bodies averaging more than two hundred members each, with a few exceeding one thousand members (Baron and Spulber, 2018). By bringing together vertical value chain participants as well as horizontal competitors and adjacent complementors, these forums exemplifythe simultaneous dynamics of cooperation and competition. When successful, the decisions emerging from these organizations have dramatic consequences,not only on the nature of upstream technological investmentsbut also on the breadth of complementary products and the speed of downstream consumer adoption. Several prominent technology platforms including Bluetooth, 3G, Wi-Fi and HDMI emerged through deliberations in formal multi-firm coordination forums.

Given the indubitable phenomenological importance of these multifirm organizational arrangements, it is indeed surprising that strategic management research has yet to systematically study them with the same import as alliances, joint ventures or inter-organizational networks. At the outset, two key lacunae are critical to address. First, our understanding of the unique circumstancesunder which such forums emerge is limited to a handful of case studies and stylized economic models of firms' actions in these settings. Without a grasp of these preconditions, it is challenging to pin down the theoretical mechanisms that can predict the nature of inter-firm deliberations and negotiations, or the specific choices individual firms might make within these coopetitive structures[1]. Second, we are limited in our knowledge of the

[1]The nature of firms' interactions and the choices they make in these forumsare emerging topics (e.g. Ranganathan et al, 2018; Toh and Miller, 2016). While these topics could also benefit from more concrete linkages to core strategic management theories, that discussion is outside the scope of this essay which focuses on the antecedents and the consequences of these structures.

conceptual drivers of "success" in multi-firm coordination, both at the firm level and at the level of the collective. Indeed, it is not even clear what constitutes success – a case in point is the WiMax standard, in which members firms were effective in achieving consensus only to fail in achieving market acceptance.

The core challenge is, as we will argue, to open the "black box" of *multilateral* coordination. Part of the challenge arises because many of the conceptual levers developed for bilateral coordination, as reflected in a large coopetition literature and the related strategy literature on alliances, are less relevant to multilateral coordination forums. A second challenge is that such forums are not homogenous, and therefore cannot be treated as an atomistic abstraction, as is largely the case in the literature on the economics of standardization. A final challenge is due to what Adner (2017) calls the "structural alignment" in his ecosystem-as-structure perspective, our broad observation being that there is an underlying structure of interdependencies and complementarities that plays a crucial role in multilateral coordination (Baldwin, 2018; Jacobides, Cennamo, & Gawer, 2018).

We address this challenge by building specifically on the properties that distinguish multifirm technology coordination forums from the coopetitive modes generally highlighted in prior research. We elaborate these distinctions using motivating field examples and propose a two part framework. First, we identify the factors that spur the formation of such coordination bodies. We propose that the potential for value creation using formal multilateral coordination structures is embodied in the industry's technological and strategic architectures. In particular, the nature of modularity in the industry in tandem with the interconnections between firms'knowledge and competitive positions, determine the extent to which multi-firm coordination becomes a feasible, and even a preferred,organizational arrangement.

The second part of our framework elaborates the value appropriation conditions that determine the extent to which multilateral coordination will be effective. Here we elucidate two distinct threats to value appropriation that are perceived by participating firms: the extent of asymmetry in future value capture and the extent of asymmetry in adjustment costs of existing resources and capabilities.The logic undergirding this approach is that, while formal technical coordination bodies promote consensus-based choices, the costs and benefits to individual member firms, arising out of accepting these choices,vary substantially (Dyer et al, 2008; Arslan, 2018; Miller and Toh, 2020). For instance, there is evidence that strategic disclosure of intellectual property during standards deliberations may boost the importance of complementary technologies also held by the same firms (Toh and Miller, 2017). Conversely, because the adjustment costs for some firms to conform to the proposed technological rules may be substantially higher, conflicts may ensue and achieving consensus on the standard may ultimately be elusive (Ranganathan et al, 2018). Without a consensus, any coordination achieved is unlikely to be absolute, with firms' independent actions outside these forums varying in the extent to which they support the common set of rules (Garud et al, 2002).

While our framework is distinctive in that it specifically addresses the multifirm technology coordination form, it also integrates across relevant bodies of work from multiple disciplines and theoretical paradigms, including existing strategy perspectives on coopetition, alliances, value creation andcapture (e.g. Dyer at al, 2008; Dyer et al, 2018; Chatain and Zemsky, 2011; Gnyawali and Park, 2011).Work in these domainshave highlighted the central importance of the cooperative, non-zero sum nature of firms jointly operating and evolving in an industry, juxtaposed against the backdrop of only partially convergent interests, and that network rather than dyadic considerations may be important (Dagnino&Padula 2002; Dyer, Singh &Kale

2008). Moreover, coopetition scholars have also highlighted that key industry-level factors such as extent of competition and product life cycles, technological factors such as convergence and radicalness of inventions, and firm-level factors such as resources, capabilities, and aspirations affect value capture considerations (Ritala and Hurmelinna-Laukkanen, 2009; Gnyawali& Park, 2009; Gnyawali& Park, 2011). Recently, there is also a growing recognition that coopetition is not static but rather evolving, requiring strategic adjustments over time among affected firms (Ansari, Garud & Kumaraswamy 2016; Cozzolino & Rothaermel 2018).

We apply and extend this rich extant understanding of coopetition to multilateral technology coordination forums in the ecosystems context. For instance, our proposition that an ecosystem's technology architecture is a key antecedent to multilateral coordination, uses a structural perspective that goes beyond the traditional firm or dyadic lens which emphasizes the strength of complementarities, informal governance mechanisms, learning and knowledge transfer routines between firms. We also build on prior research that highlights value capture and creation logics under a coopetition lens (e.g., Ritala and Laukkanen 2009; Gnyawali and Park, 2011; Ritala and Tidström 2014) and expand these logics to multilateral coordination using an ecosystems lens. In the process of deriving our framework, we also hope to clarify its boundaries within the overall typology of alliances and other collaboration structures. Our intended contribution is to provide a foundation that can spur further theoretical and empirical research focused on these coordination structures.

Multilateral technology coordination: departure from existing strategy perspectives

While the study of inter-firm cooperation and collaboration has been a longstanding area of research in strategic management, this research attention has been predominantly devoted to bilateral ties or strategic alliances between pairs of firms (Dyer & Singh; 1998; Anand and

Khanna, 2000). Consequently, the literature that examines when these ties form, between which firms they form, and to what effect, has typically focused on either dyadic strategic factors (e.g. Chung et al, 2000; Dyer and Singh, 1998; Mowery et al, 1996; Mowery et al, 1998; Aggarwal, Siggelkow and Singh, 2011; Arino and De La Torre, 1998; Gulati and Singh, 1998) or extra-dyadic structural factors,where the broader network mechanisms are also derived from the pattern of interconnections between pairs of firms. (e.g.Gulati, 1995; Gulati and Gargiulo, 1999; Ahuja, 2000; Zaheer and Bell, 2005; Ahuja et al, 2009; Ghosh, Ranganathan, & Rosenkopf, 2016)[2].

However, multifirm technology coordination arrangements in ecosystems are distinct from traditional bilateral ties on several dimensions. Table 1 summarizes the key differences between these two structures that are relevant to understanding the formation and outcomes of such forums.

<<Insert Table 1 about here>>

Objectives. First, the objectives of multiparty technical coordination are fundamentally different from the objectives of bilateral coordination mechanisms(e.g., dyadic strategic alliances). In the alliance literature, dyadic alliances are broadly categorized as R&D (knowledge-generating) alliances (e.g. Rothaermel and Deeds, 2000) or commercialization (knowledge-leveraging) alliances (e.g. Lavie and Rosenkopf, 2006). For instance, pharmaceutical and biotech firms collaborating to develop molecules using bioinformatics and automated DNA sequencing constitutes an R&D alliance, whereas a fabless semiconductor design firm licensing the production and marketing of its technology to a semiconductor foundry/manufacturing firm constitutes a commercialization alliance. Importantly, whether the collaboration activity is upstream or downstream, the focus in dyadic alliances is on exploiting

[2] A substantial research stream that uses the "alliance portfolio" lens also examines bilateral ties between firms

the *existing complementarities* between the resource bases or knowledge bases of pairs of firms. Similarly, empirical work in the coopetition domain has typically focused on product-market objectives such as the rollout of a new disruptive technology within an established industry (Ansari, Garud and Kumaraswamy 2016) or the building of a (collective) quality identity in coopetitive efforts with others (Mathias, Huyghe, Fridand Galloway2018).

In contrast, in multi-firm technology coordination, the focus is on the *potential tocreate complementarities* at the industry level. For instance, when firms get together in standards forums, the objective is to achieve consensus on a common set of rules that can then spur innovations in specific components. By resolving technical interdependencies and designing to a unified set of rules, firms can achieve compatibility across their technologies.When hundreds of such firms achieve compatibility, they then dramatically reduce technical uncertainty and increase the value of complementary options for end-consumers.

Governance. While bilateral ties are actively governed both by formal and by relational governance mechanisms (Reuer and Arino, 2007; Hoetker and Mellewigt, 2009; Dyer, Singh and Kale 2008), multilateral forums are managed through decentralized committees and workgroup structures(e.g. Reuer and Devarakonda, 2016). In technical standards forums, the rules of inter-firm interaction are defined by an umbrella standards body such as ANSI, IEEE, INCITS or the ITU, that publish, certify and disseminate the agreed-upon standard. These rules cover both the process of development (e.g. from proposal submission process to ratification and final acceptance of the rules) as well as the allocation of rights and responsibilities to firms (e.g. intellectual property disclosure rules, voting rights).The key distinction between bilateral and multifirm bodies lies in the intent of the governance mechanism(s) used to manage their activities. While formal and relational governance[3] mechanisms in bilateral tiesare meant to safeguard a firm's knowledge from appropriation by the partner (e.g. Kale, Singh and Perlmutter, 2000; Gulati and Singh, 1998; Ritala and Tidström 2014), align incentives across the two firms to co-invest (Agarwal, Croson and Mahoney, 2010), and generally limit the unforeseen liability or negative consequences of transacting across firm boundaries, committee governance mechanisms in multifirm bodies are oriented towards enhancing transparency and information sharing, allowing for democratization of development, and encouraging debate and divergence in opinion across firms. However, because committee governance mechanisms are not contractual in nature, disclosure of information does hold risks of knowledge spillover for firms. These considerations, in turn, have implications for both the shared value creation process (i.e. the analogy of creating a bigger pie together) as well as attempts at individual value appropriation (i.e. the analogy of obtaining a bigger piece of the shared pie).

Commitment.Commitment to partner(s) is another important distinction between bilateral and multilateral coordination. When formal contracts are used for bilateral coordination, as is often in the case in traditional alliances,commitments are quasi-irreversible sincenon-compliance with contractual termscan result in substantial costs for the parties. On the other hand, although the lack of contracts makes the technical specifications that emerge through multilateral coordination non-binding, a sufficiently widespread agreement obtained within the auspices of these bodies also makes it very difficult for firms to "go-it-alone" and flout the agreed-upon rules (Anton and Yao, 1995). Thus, the degrees of freedom afforded by the non-binding nature of

[3]It is important to note that in multi-year standards-setting initiatives (e.g. the WiFi standard), the same set of firms (and firm representatives) may repeatedly interact over a period of time. Similarly, in the information technology and telecommunications sectors, the same firms may also interact across different standards bodies. Both repeated interactions within and across forums may serve the same function as relational governance in traditional alliances by reducing frictions and increasing trust.

multifirm coordination forums really depends, in part, upon the extent of consensus achieved through discussions and debates with other firms.

While bilateral coordinationis generally fixed-term, particularly when formal governance is in place (with the parties often renewing agreements contingent on their performance and strategic directions), the activities in a multilateral coordination body are temporally unbounded. Indeed, several standards committees formed in the 1990s such as WiFI (IEEE 802.11) are still active today with continued participation from the initial firms. This is because the “rules” that emerge from these forums require constant updating with ongoing innovations and technology development across different ecosystem components. This in turn also requires firms to invest in sustained participation in order to influence these choices. Similarly, multifirm coordination forums can also allow unrestricted membership (with low entry barriers in terms of membership fees) and thus unlike formally governed bilateral partnerships, firms do not have control over their “partners”. Likewise, the absence of contracts, the rules and norms of consensus-driven decision-making and the sheer size of these bodies make it virtually impossible for any single firm to predict and control the behavior and choices of other firms in the forum.

Value creation. Value creation is a foundational consideration in the scholarly work on bilateral coordination. A basic but important recognition in the coopetition tradition is that bilateral coordination may be among competitors, in which case the “game” being played out in coordinating firms is positive sum, but not purely cooperative due to asymmetric competitive pressure(Dagnino&Padula 2002). More specifically, work in coopetition as well as other research has considered the role of complementary assets (Teece 1986; Ritala and Hurmelinna-Laukkanen 2009) and learning from one another (Khanna, Gulati and Nohria 1998;

Dussauge,Garrette and Mitchell2000; Ritala and Tidström 2014) as the sources of value creation in bilateral coordination between firms.

While value creation is also at the heart of multilateral coordination efforts, there are complicating factors, perhaps most salient of which are a greater complexity (due to multilateral interdependencies) and a lack of formal controls, such as contractual mechanisms and/or hierarchies, to govern coordination. As such, the evolution towards an effective "alignment structure" (Adner 2017) -- the technological structure of interdependence among components in the underlying ecosystem and consequent positions and roles of participating firms – is essential for value to be created in multilateral coordination. We discuss this notion further in a subsequent section.

Value capture and the nature of inter-firm influence.In the coopetition literature, differential value capture arises when partners extract private benefits that then reduces the pool of common benefits (Arslan, 2018). Here, firms may restrain from such private benefit extraction only when the potential for common benefit is high and when there is symmetry in the distribution of these common benefits among partners (Arslan, 2018). Further, drawing from work in alliances, firms can manage the potential for such asymmetric value appropriation by adjusting the governance structure of the relationship appropriately (e.g. Gulati and Singh, 1998). Similarly, firms' market power and bargaining positions (e.g. Lavie, 2007), the strength of their alliance function and capabilities (e.g. Kale, Dyer and Singh, 2002) or the centrality of their relational positions in strategic networks (e.g. Gulati, Nohria and Zaheer, 2000; Lavie, 2006) allowsfirms to architect favorable bilateral ties and to manage the collaborative relationship to fruition. However, the effect of analogous capabilities and positions tend to be more nuanced in the multilateral context as negotiationeffectiveness is rooted in firms' abilities to propose, deliberate and resolve issues across large numbers of firms on the basis of perceived technical merit (Ranganathan et al, 2018). Ultimately, the extent of value a firm can appropriate because it joins a multilateral forum is not foreseeable ex-ante but is *endogenous* with regard to the course of interactions with others on the forum and the emergent set of rules.This is distinct from the way value capture has been theorized even in recent work on ecosystems where innovation has already occurred and the focal firm's actions are restricted to building consumers, engaging incumbent firms or continuously adjusting its technology (Ansari et al, 2016). In effect, because of the decentralized committee-based governance of multilateral forums, the course of interactions with others cannot be fully controlled by a powerfully positioned or technologically superior firm. Indeed, when leading firms aggressively push for choices that favor them, it can have adverse consequences for the legitimacy of the outcome of coordination[4] (Garud et al, 2002).

These distinctions highlight the uncertain nature of private benefits accruing to firms that participate in multiparty forums. What then propels firms towards embracing this type of organizational arrangement? Early studies in strategic management proposed rudimentary factors such as firm size and rivalry (e.g. Axelrod et al, 1995) as antecedents to multilateral alliance formation. However,they do little to explain the membership of contemporary standards bodies or for that matter whether coordination outcomes are impactful. Indeed, most large multifirm technology coordination forums are remarkably heterogeneous on many observable dimensions, and they emerge out of coordination between firms that are fierce rivals in technological or product-market spaces. Along these lines, the membership rosters of most standards bodies indicate the presence of both large established incumbent firms as well as small entrepreneurial

[4]This is not to suggest that powerful firms or coalitions of firms cannot influence others outside of the deliberations of multilateral forums in ways that benefit them in the consensus rules. The point advanced here is that it is *more* difficult for such firms to exert *complete* control than in the case of traditional alliances.

ones, thus suggesting that motivations to form such arrangements are more nuanced (Baron and Spulber, 2018). Subsequent scholars have made some exploratory headway in examining processes that engender larger consortia (e.g. Doz et al, 2000), but such explorations haven't yet yielded theoretical frameworks that can account for the distinctive context of technology coordination that characterizes such organizations.

Similarly, we know little about *when* such coordination structures might yield a set of rules that spur innovation and growth. When is this mechanism effective? The proliferation of such arrangements in overlapping technological spaces (for e.g. Baron and Spulber(2018) document a large list of SSOs in information technology, communications, software and electronics) suggests thatthese forums are not able to fully influence or control the trajectory of innovation in their sectors. Moreover, the simultaneous rise and success of platform-based ecosystems such as Apple's iOS, Google's Android or Facebook, where a powerful firm unilaterally lays down the architectural rules by eschewing explicit coordination with complementors, underscores the possibility that under certain conditions, multilateral coordination structures are ineffective and other competing organizational forms may arise. Neither the classical strategy literature on alliances and the relational view, nor the adjacent perspectives on coopetition and value appropriation have examined these issues.

On the other hand, the more traditional economics perspectives on technology coordination are well-grounded, yet adopt stylized models of standards choices (e.g. Besen and Farrell, 1994; Lerner and Tirole, 2006) that do not fully capture the richness and complexities of these contexts. For instance, the economics of innovation literature has largely overlooked the tension of value creation and value appropriation that is central to such coopetitive settings, as the attendant research focus has been on comparing the coordination efficiency of multilateral forums with that of markets (e.g. Farrell and Saloner, 1988; Simcoe, 2012), with the broad understanding that multilateral forums presumably exist because firms find it less costly to engage in collaboration than to fight attritional standards wars in the marketplace. In other words, multilateral coordination forums are argued to be more effective when network effects accrue as part of the coordinated value creation process and when these effects are *known* to be greater than the benefits of going-it-alone (e.g. Farrell and Saloner, 1988). In this research, the nature of inter-firm interactions and deliberations within these committees is not emphasized or underscored– the assumption is that highly rational (and powerful) firmscan accurately assess the benefits or payoffs of specific solutions and make concessions or side payments to compensate for others' adjustment costs in agreeing to a common set of technical rules.

Similarly, when research has looked at the presence of multiple such forums, the focus has typically been on how firms should decide which forum to join (e.g. Lerner and Tirole, 2006; Axelrod et al, 1995), again assuming little to no uncertainty in the outcomes of and interactions within these forums.However, empirical research in this tradition has also provided solid evidence and thereby grounds for a deeper theoretical inquiry into both individual firm actions and collective outcomes within these multi-firm organizations. In particular, the availability of patent data from these forums has allowed researchers to establish a consistent set of findings that point to value appropriation concerns from intellectual property and technology being a key source of contention. While Rysman and Simcoe (2008) find that intellectual property disclosed as part of standard-setting becomes foundational in the evolution of the associated technology, relatedly, Augereau, Greenstein and Rysman (2006) suggest that conflicts over technology choices can lead to issues in achieving a consensus technology standard. Similar concerns are highlighted in Farrell and Simcoe (2012) and Lemley and Shapiro(2007) as causing holdups and slowdowns in the coordination process.

Antecedents of multifirm technology coordination organizations

While we integrate the above ideas from strategic management and economics, we also anchor them more directly within the ecosystems and technology coordination contexts to propose a conceptual framework that identifies factors supportingthe emergence of multifirm coordination structures. Here, we draw directly upon both Adner (2017)'s conceptualization of an ecosystem as "the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition[5] to materialize" (Adner, 2017, p.42), and Jacobides et al (2018)'s definition of an ecosystem as "a set of actors with varying degrees of multilateral, nongeneric complementaritiesthat are not fully hierarchically controlled" (Jacobides et al., 2018, p.2264). Together, by underscoring non-hierarchical, multilateral interactions between firms to realize the value of their complementarities, these definitions capture the essence of multifirm technology coordination organizations.

Here, we are interested in understanding the conditions under which multifirm coordination structures such as standards forums, emerge as a preferred organizational mode to develop such analignment structure among a focal set of firms.Most basically, we propose that these conditions will *increase theurgency for firms in the ecosystemto utilize multifirm coordination arrangements* in order to create value (i.e. realizethe joint value proposition). We conceptualize two categories of factorsthat, albeit interlinked, are nevertheless distinct enough to be considered separately:

[5] The idea of a value proposition is analogous to the potential value that can be created in the ecosystem should an effective alignment structure emerge.

(a) Technological architecture factors, arisingfrom prior designconsiderations, that have resulted in a set of identifiable technical modules (components), with a pattern of interconnections between them.

(b) Strategic architecture factors, arisingfrom the prior actions of firms,that have resulted in their existing resource and competitive positions, with a pattern of interdependencies between them.

<<Insert Figure 1 about here>>

(a) *Technological architecturefactors.*

The most basic architectural factor driving multifirm coordination is *modularity in design* (Baldwin and Clark, 2000). Modularity in design varies across different industries but also within the same industry wherein different value propositions can implicate different modules. Indeed, Schilling (2000, p.312) defines modularity as "a continuum describing the degree to which a system's components can be separated and recombined, and it refers both to the tightness of coupling between components and the degree to which the 'rules' of the system architecture enable (or prohibit) the mixing and matching of components."Ecosystemsin industries such as wireless telecommunications have thrived because of modular architectures - as Simon (1962) observed, modularity reduces an intractable web of technical interdependencies into smaller, manageable subsystems that are amenable to efficient design and innovation. Without modularity, systemic innovations that require coordinatedmultifirm actions are rare and technical change is typically limited within the boundaries of firms that operate in an integrated fashion (Langlois, 2002). This in turn can hinder the evolution and growth of the industry itself. Pisano

(2006) drives this point home in suggesting that the biotechnology industry has languished precisely because it is not amenable to modularization.

While it is well established that modularity directly affects the evolution of technological systems (Baldwin and Clark, 2000), our viewpoint is that it also affects the promise of coordinating value propositions through multilateral forums. First, we propose that the *extent of modularity* – i.e. the number of different modules or components that need to interact in order for the focal value proposition to materialize (Adner, 2017), will increase the likelihood of formation of multifirm coordination structures. To understand why, recall that most basically "[higher] modularity shifts the locus of innovation [from the ecosystem as a whole] to the component or subsystem level" (Pisano and Teece 2007, p.284). This, in turn, engenders greater specialization, an increased division of labor, and allows firms to independently innovate within modules (Garud and Kumaraswamy 1995). If the modular positions and the interfaces between them can be standardized, then on the demand side, modularity can boost end-user functionality by a "mix-and-match"approach, where components can be recombined downstream to create different varieties of systems or end-products (Ganco, Kapoor and Lee, 2020). In effect, while on the one hand modularity tends to fragment innovative activity by distributing the locus of innovation more broadly across a greater number of actors, on the other hand such distributed innovation also seedsfuture multilateral complementarities (i.e. the network effects).It is precisely these multilateral complementarities that constitute the value proposition on which alignment across the affected actors is desired – as Jacobides et al (2018) underscore, a distinctive feature of the alignment structure here is that it must be coordinated without vertical integration.

Increasing modularity and distributed technical progress give rise to systemic innovation opportunities but also pose new technical questions on module positions, scope of activitieswithin them, as well as the links or interfaces between them (Adner, 2017). These questionsare elements in the alignment structure that firms need to ultimately converge on to realize the focal value proposition. The greater the breadth of modules implicated in the value proposition, the more effective multilateral deliberations in formalized forumscan be as coordination mechanisms.

But what determines the extent of modularityin such alignment structures? An influential factor is the maturity of technologiesunderlying the modules. When technologies are still in a nascent stage in their life cycles, many modules will remain emergent because substantial price/performance improvements continue to be possible not only with incremental innovation within established modules but also with architectural experimentation at the system level (i.e. the introduction of new modules, activities or links). Relatedly, the effortsof both established and entrepreneurial firms will be focused on discovering and commercializing such innovations rather than engaging in large scale coordination to create a joint value proposition. Any interdependencies that exist at this stage can likely be managed either through vertical integration or using targeted dyadic strategic alliances. Indeed, the coordination overheads that multilateral structures entail may outweigh their potential benefits at this point in the technology life cycle. For example, although the IBM PC was a modular product, the extent of modularity was far lower in the early 1980s where substantial functionality was still embedded into the motherboard and the operating system. Innovations in the early days were the result of only a handful of firms such as IBM, Intel and Microsoft. But as the technologies evolved and the established firms realized the value (i.e. from the complementarities) of further splitting the architecture into smaller modules to allow greater downstream recombinations (Baldwin and Clark, 2000), modularity and module owners increased, resulting in a greater need for multilateral coordination. As the PC industry's technology architecture evolved in the 1990s, many modules emerged, with newer interfaces and linkages to different categories of peripheral devices and various kinds of application software.In turn, this not only triggered substantial entrepreneurship in the industry and demand for complementary products, but also corresponded to the emergence of INCITS (International Committee for IT Standards), the first large scale multilateral coordination forum in the industry.

Second, we propose that the *variability in innovation rates across modules* –i.e. the divergence in ratesof technological change across modules – will positively affect the emergence of multifirm coordination structures. The rate of technological change in a module ultimately has roots in the scientific and engineering advances that are specific to the functional activities performed by that module. For example, performance improvements through innovation in microprocessors is driven by lithographic advances in solid state electronics while innovation in hard disks is driven by increases in the areal density of magnetic storage. In essence, if the rate of technological change is comparable across the modules of an ecosystem (for e.g. because they draw on largely overlapping scientific or engineering knowledge domains), then the potential returns to large scale multilateral coordination are limited because the value gained by implementing an innovation in one module is already aligned with the value gained by implementing comparable innovations in other modules. Said differently, module owners can independently innovate or adapt their modules to contemporary innovations in other modules because both technical choices and incentives are similar across the modules. However, if technological change and discontinuities are fundamentally different across components/ modules, then realizing a value proposition requires careful deliberations about the technical options and their adjustment costs across various module owners. For instance, in the computer industry, because hardware and software follow very different innovation trajectories,hardware firms and software firms benefit more from formal coordination of investments and interoperability choices.

A final factorthat diminishesthe urgency for multilateral coordination is the extent to which *modules are disproportionately critical* tothe focal value proposition. Consider the case where firms do not formally coordinate to achieve alignment. Instead of the overall value proposition, each module owner may then be able to create some subset of the total value proposition through independent innovation. The distribution of such piecemeal value created will be asymmetric across firms precisely because modules differ in their criticality with regard to the performance of the focal system. Thus, marginal benefits to innovative efforts will differ across module owners such that the greatest benefits accrue to the firm(s) that control(s) the most critical module(s). While the notion of a critical module is analogous to the concept of a bottleneck component discussed in other work on ecosystems (e.g. Kapoor, 2018), the point advanced here is that *variance*in criticality across modules will reduce coordination urgency because owners of critical modules do not need to engage in multilateral deliberations to realize the focal value proposition. A combination of independent innovation along with a handful of bilateral arrangements with closely interdependent components may allow them to rapidly introduce innovations in the critical component. For instance, Intel’s trajectory of microprocessor development in the PC industry or Apple’s iOS upgrades do not need coordination within multilateral forums. The entire ecosystem synchronizes investments based on the development plans of these players precisely because the component they control is excessively or disproportionately critical to the performance of the overall system.

(b) *Strategic architecture factors.*

Technological architecture factors outside the complete control of firms, that are driven by the advancements and constraints in basic sciences or engineering do not fully determine the antecedents or outcomes of multifirm coordination (Tushman and Rosenkopf, 1992). As Baldwin and Clark (2000) note, "modularity does not arise by chance, but is the intentional outcome of conscious design effort." Thus, modules, including their positions and the flows or links between them, evolve over time through the efforts of firms to shape the industry's technicalarchitecture to their advantage. Over time, these efforts endow firms with heterogeneous knowledge resourcesand distinct competitive positions, with distinctinterdependencies between them. We propose that the structure of these knowledge resources, the structure of these competitive positions and the extent to which complementarities are multilateral, influence firms' collective urgency to create value through multilateral coordination.

1. <u>Structure of inter-firm knowledge:</u>As firms enter ecosystem modules and develop components, they accumulate path-dependent technical knowledge about the product-system (Patel and Pavitt, 1997). Naturally, the particular knowledge that a firm gains is primarily related to the specific component(s) or module(s) that it chooses to focus on, and, as a result, variation in the specialization and scope of firms across modules will, over time, lead to a dispersion of knowledge across firms. Additionally, firms may also strategically develop knowledge about components or modules that they do not specialize in – whether such knowledge pertains to upstream, downstream or complementary components, or encompasses integrative knowledge about the entire product-system, it is well-established that knowledge boundaries may not completely align with firms' product-market boundaries (e.g. Brusoni et al, 2001). We propose that the interconnections among firms with respect to such knowledge will influence multilateral coordination tendencies in two distinct ways.

First, the greater the extent to which the focal value proposition requires integration across *knowledge elements that are distributed* across firms,the more likely it is that multilateral coordination will be required. Extending the previousexample, if Intel were to make a path-breaking discovery that completely altered the technical tradeoffs in semiconductordesignfor mobile devices (and thus necessitated a radical trajectory shift), it may still need to coordinate the technology commercialization choices with foundries, integrators, assemblers, handset firms and other complementors such as mobile network operators, if it lacked the relevant component and complementary knowledge across the product-system. Without such coordination, any new chipsets that Intel releases will be incompatible with existing components managed by other firms. However, if Intel already possessed the entire knowledge required to commercialize this value proposition, then rather than engaging in multilateral coordination, it may be able to develop its novel technology unilaterally to be compatible with other ecosystem components.

Second, the more *divergentthe foundations ofknowledge* firms hold, the less likely it is that they will seek coordination through multilateral forums. To understand why, it is important to underscore the goal of such multilateral coordination: the development ofconsensus rules such that firms' independently developed technologies and products can interact.But this goal presupposes that it is indeed feasible for coordination to yield sufficient common ground such that the focal value proposition can be realized. However, firms' technologies may be fundamentally incompatible because they build on different knowledge bases and make divergent assumptions or contradictory tradeoffs in design. In such ecosystems, it is unlikely that firms will even attempt to pursue coordination. A more likely outcome is the formation of opposing coalitions of firms or rival consortia that then compete in winner-take-all battles in product-markets. Indeed, history is replete with examples of "standards wars" between incompatible competing technologies, from railway track gauge battles and electricity transmission (AC vs. DC) standards wars in the nineteenth century, to video tapes (VHS vs. Betamax) and DVD disc (BluRay vs. HD-DVD) format wars in the late twentieth century. For example, in the BluRay vs. HD-DVD format war, the BluRay format was physically different from traditional DVDs on several critical dimensions including laser wavelengths, numeric apertures, thickness, layer size and spacing between pits, thus rendering it fundamentally incompatible to pursue any kind of coordination with solutions based on the traditional DVD format.

2. <u>Structure of inter-firm competition:</u>The *structure of competition* in the ecosystem will affect the pressure to seek multifirm coordination solutions to achieve the value proposition. We envision that both upstream competition (i.e. crowding in the technological space), and downstream competition (i.e. crowding in the product-market space) are relevant and distinct considerations. When firms have a high degree of redundancy across their upstream technology development efforts, then multiple technical alternatives to solve the same end-user problems can proliferate. This can hinder both the development of compatible complements and widespread consumer adoption, thus increasing the incentivesto devise a multilateral solution to streamline these overlaps. In a similar vein, when product-market rivalry is more acute and competitive positions are fragmented, no single firm derives excess rents from an advantageous downstream resource (Barney, 1991; Chen et al., 2007).Here, it is less likely that powerful firms with superior downstream positions (Porter, 1980)will block larger coordination efforts upstream as a way of preserving the status quo and thereby their

advantage. Additionally, even if firms can continue to leverage current commercialization assets for standardized technologies and products, no single firm holds an advantage in capturing *future* rents generated from complementarities that emerge from multilateral coordination. Indeed, in such scenarios, unlocking new value propositions through ecosystem-wide coordination that can enable systemic innovation,is palpably more promising. Ranganathan et al (2018) find some support for this argument - simultaneous competition in both a firm's technology domain and its product-market domain is associated with an increased urgency to achieve alignment through standards discussions. In other words, firms that face the most oppressive competitive conditions are the most amenable to a coordinated ecosystem. Thus, increased competition does not equate with decreased cooperation, a point underscored by Dagnino (2009)'s coopetition study.

3. Extent to which complementarities are multilateral:Finally, value creation in ecosystems can be dramatically spurred through the advent of multifirm coordination structures particularly if there is a high potential for the ensuing agreements to unlock *complementarities that are* (correspondingly*) multilateral* in nature (Jacobides et al, 2018). To understand why, consider that the urgency to coordinate to develop new ecosystem-wide interoperable standards tendsto correspond to the promise of a new enabling technology such as wireless transmission (e.g. CDMA), nanotechnology or even the internet (e.g. IETF). These enabling technologies are typified by their capacity to spur "ongoing technical improvement" and to "enable complementary innovations in application sectors" (Teece, 2018, p.1369). For instance, nanotechnology promises to increase storage capacity and temperature resistance of semiconductors by several multiples. When an enabling technology can spur complementary

innovations across the industry (Adner and Kapoor, 2010), coopetition is preferred, or perhaps even mandated, in order to efficiently resolve the coordination problems that may hinder technology commercialization. In such settings, the scope of coordination to realize the value proposition of a focal innovation becomes even more complicated, and approaches that rely on traditional inter-organizational mechanisms are ineffective. A series of bilateral agreements are unlikely to resolve such interdependencies that simultaneously affect more than two firms (Adner, 2017; Jacobides et al, 2018).

Thus, while multifirm coordination mechanisms do serve to define standards that ensure the basic interoperability required to enable a complete system- for instance, the track width of a railroad system (Anton and Yao, 1995) or the dimensions of an AA battery (International Electrotechnical Commission) – they are principally engines of innovation and value creation, particularly where complex systems technologies are involved. As Teece (2018, p.1381) notes, “the standards process [i.e., the platform-shaping process] develops, assembles, and anoints new (upstream) technologies with strong implications for downstream innovation. The complex technical details … are likely to be hammered out [in a forum] for engineers from participating firms to contribute technology and to shape the standard”.

To ground this idea in a real-world example, consider mobile phone technology. Since the 1980s, demand for cellular phones had been growing but largely latent because the regulatory structure of the telecommunication industry had resulted in slow, incremental innovation with a view to preserving the rents from wireline operators’ technological capabilities (West, 2006). The resulting network capacity was therefore the main constraint to delivering the value proposition. Qualcomm’s Code-Division Multiple Access (CDMA) technology, which by some claims represented a dramatic improvement of 15x to 20x the capacity of existing mobile communication technology, thus held the potential to a superior value proposition. By massively improving the utilization of bottleneck resources (in this case network capacity) through new methods (in this case digital communication), CDMA unlocked novel sources of value. It eventually spurred a major transition from the first-generation analog-based mobile platform - Advanced Mobile Phone Service (AMPS) - which was the dominant design at the time (West, 2001). A parallel technology – GSM – that was adopted as the shared platform in the EU, triggered a major growth in mobile communications in those countries as well.

Thus, while the implementation of CDMA or GSM across the ecosystem required coordinated investments across a variety of firms (e.g. handset makers, wireless operators that owned wireless spectrum, base station transceivers, controllers and switching centers), the value creation that was associated with the technology went beyond interoperability to unlock hidden complementarities.

Effectiveness of the multifirm technology coordination mechanism

As several instances of multilateral coordination structures abound in technology-driven industries, a natural direction of inquiry for strategy scholars is to examine their effectiveness. In our view, "effectiveness" entails achieving both a sufficiently broad consensus across the affected firms, as well as over a wide enough range of interdependencies to spur systemic innovations. Without a broad consensus, it is unlikely that there will be critical mass of aligned firms or interconnected modules to realize the multilateral complementarity potential. As a result, firms may ignore any consensus rules that emerge from the coordination, and instead persist with idiosyncratic or proprietary solutions. This is likely to stymie innovation both on the producer side by constraining innovation investments, and on the demand side by limiting the ability of downstream actors to mix and match compatible components (Ganco, Kapoor and Lee, 2020). Additionally, effectiveness can also be conceptualized in terms of the time it takes for a consensus solution to emerge - the longer it takes, the more likely that firms will independently develop incompatible technologies and attempt to create a de-facto standard.

Although firms are drawn to coordinate within the confines of these coopetitive structures for the value creation reasons mentioned above, it is not apparent that concerns of *value appropriation* are necessarily resolved merely through the operating procedures and rules of these forums. Most basically, because technology coordination results in standardized rules that necessarily reduce the number of feasible technological alternatives in the ecosystem, it can reduce the potential for differentiation and rent generation by firms. As Garud et al (2002) point out, “[S]tandards both enable and constrain. This structurational property of standards makes it difficult for actors to forge agreements that enable activities in the present but have the potential to constrain activities in the future”(Garud et al, 2002: p. 207). Because the participants in these forums are ultimately representatives of profit-making enterprises, they will act both to preserve their firms’ existing investments and competencies (i.e., their sources of current differentiation and rent generation), and to push the group towards adopting multilateral solutions that differentially advantage them (i.e., their sources of future differentiation and rent generation). Indeed, studies in the coopetition tradition suggest that although value creation in coopetitive settings is facilitated by shared interests regarding the growth of specific technological or market domains, it is this very overlap in interests that is also likely to provoke tensions around how the value is to be split across the collaborating firms (Arslan, 2018; Ritala and Hurmelinna-Laukkanen, 2009). These tensions can be exacerbated in ecosystems settings because unlike traditional industrial settings, where formal governance arrangements such as contracts or equity arrangements can adjudicate the division of valuein alliances, there are no well-defined mechanisms in technology coordination forums.

A major distinction in these forums is that although the rules devised within their auspices can create the foundation for substantial value creation in the ecosystem, the actual actions that will generate and appropriate this value, are conducted outside their boundaries and as a result fall outside their governance scope. Thus, the substantial uncertainty in future value appropriation will affect firms' value creation efforts in the present within these coordination forums, and thus the urgency of cooperation (Ritala and Hurmellina-Laukkanen, 2018). In essence, the seeds of any possible value appropriation asymmetry across the firms are sown in the nature of the rules themselves – rules that are seen to differentially favor one firm or a subset of firms are likely to be heavily contested. Ultimately, the composition of heterogeneous firms, with idiosyncratic path-dependent resources and capabilities will result in a tussle for a relative advantage in this future value appropriation race. This in turn will have implications for the effectiveness of multifirm structures as coordination mechanisms.

We conceptualize these value appropriation concerns as being rooted in two apprehensions - the *asymmetry*(across participating firms) *in future value capture* and the *asymmetryin*their *future adjustment costs*. In our view, these are not necessarily actual asymmetries but <u>perceived</u> asymmetries based on interactions within forums and an incomplete assessment of the value proposition's potential.

<<Insert Figure 2 about here >>

The asymmetry in future value capture concern arises from three distinct yet conceptually inter-related considerations. These considerations enter the calculus of decision-making for firms as they contemplate extending support for or resisting the proposed multifirm technical rules in these bodies. First, is the potential for asymmetry in *technology licensing.* The revenues obtained from licensing is a key source of economic rents in technology ecosystems that are subject to network effects. By embedding proprietary technology solutions directly in an ecosystem-wide standardized compatibility solution, firms can create powerful and irreversible sources of advantage. Although many forums have rules in place to force firms to disclose relevant intellectual property and license these on reasonable terms, these rules are still fairly ambiguous and tend to lack legal enforcement ability (Layne-Farrar, Padilla and Schmalensee2007;Contreras 2013, 2015).Indeed, if downstream resources are generic and the product-markets are highly competitive, then intellectual property licensing may be the only source of primary value appropriation and generative appropriability for participating firms. As a result, selective inclusion of some firms' IP in the standard may stymie coordination, as evidenced in numerous high-profile standard-based conflicts over IP such as those involving Rambus in computer memory and Qualcomm in mobile wireless technologies (Layne-Farrar, Padilla and Schmalensee2007;Contreras2015).

Second, is the potential for *asymmetry in non-generic complementary resources* that are central to value creation. Beyond the direct use of a firm's intellectual property, a more nuanced or indirect way to obtain an advantage is possessing complementary technologies that become essential once the solution is adopted. Toh and Miller (2017) demonstrate evidence for this idea, finding that disclosing relevant IP may indeed enhance the value of its complementary technologies, but with the caveat that it might also expose such technologies to expropriation . Beyond complementary technologies, firms may also possess other required downstream complementary assets (e.g. Tripsas, 1997) that may endow them with at least a temporary advantage in commercializing the standard.

A final point is the potential for *generative appropriability*, an idea introduced by Ahuja et al (2013). Generative appropriability differs from primary appropriability (the technology licensing or complementary asset mechanism illustrated above) in that it refers to a firm's ability to capture rents from *future* inventions spawned because the ecosystem aligns in a certain way on a multifirm solution. In the case of technology coordination forums, generative appropriability is higher when there is an established trajectory of technological rules with newer versions of rules maintaining "compatibility" with older versions. Here, although new inventions must conform only to the most recent set of standardized rules, they effectively build on prior inventions that conform to an earlier set of rules (Ahuja et al, 2013). The potential for generative appropriability is particularly high in the context of enabling innovations of the type discussed in the preceding section on value creation (Gambardella et al, 2021; Chen et al, 2021). Because enabling innovations are not fully developed technologically, the nature of future related technologies and products is of course more uncertain but at the same time, these innovations also hold the potential for greater upside. Each firm engaged in technology coordination must therefore ensure that thevalue it appropriatesfrom a particular generation of the enabling technology can be used in a cumulative sense to seed future benefits that can be privately captured (Ritala and Hurmelinna-Laukkanen, 2018).In other words, when the stakes are higher, we would expect that there is greater contentiousness among firms to embed their technologies selectively into the alignment structure. . Overall, we conceptualize that the value appropriation concerns related to asymmetry in future value capture will decrease the effectiveness of multifirm coordinationwhen the potential for rents from technology licensing, non-generic complementary assets, and future spawned inventions is greater.

The second category of value appropriation concerns illustrated in Table 3, is related to the asymmetry in future adjustment costs that is necessitated by a move to a multilateral, standardized technology coordination structure from the existing interconnected ecosystem. These adjustment costs arise precisely because coordination does not happen in a vacuum but involves and affects an existing system of incumbent firms that have made path-dependent investments in component, architectural (Henderson and Clark, 1990) and relational or network competencies (this point is highlighted in Ranganathan and Rosenkopf (2014)). For example, competition for early mobile wireless standards came from both firms with substantial capabilities in fixed wireless metro area applications and firms who had substantial mobile telephony capabilities. One prospective standard, WiMAX, favored the former while another prospective (and eventually dominant) standard, 3GPP, favored the latter. Adjustment costs would have been lower for firms from a fixed wireless heritage had WiMAX won out, but in the end the adjustment cost advantage went to the mobile telephony firms.

The idea of adjustment costs recognizes that patterns of prior linkages in different technical, product and relational domains may hold the key to whether these forums successfully deliberate or are mired in deadlocks. We recognize the possibility that all three types of competencies – *technical*, *architectural* and *network* or *relational* - may be subject to erosion, because the proposed rules force the winnowing of technology and product alternatives in the ecosystem. While technical competencies can be conceptualized as the module or component-level technological capabilities of individual firms, architectural competencies are inter-component integrative capabilities. Both technical and architectural competencies may be rendered less valuable because of new multilateral rules that affect component positions and their interfaces (links and flows). Similarly, firms may also have strategic network resources based on their pattern of bilateral inter-organizational relationships with other firms, that allow them to extract rents (Lavie, 2006) in systems where no broadly accepted alignment structure exists. A large body of research on alliance networks has established how relational, positional and structural embeddedness in such structures can confer informational advantages to firms (e.g. Gulati and Gargiulo, 1999). But new multilateral rules emerging from the coordination have the potential to render such network positions less valuable and thereby diminish the associated rents.

Ultimately, the selection mechanism of coordinated technological standards, imposes adjustment costs on firms that may have technical implementations that differ substantially from the alignment structure proposed, and competence erosion costs for firms whose robust portfolios of bilateral relationships are at risk to be substituted by a single multilateral alignment structure. Overall, we propose that effectiveness of multilateral coordination diminishes if the asymmetry concerns relating to adjustment costs outweigh the perceived advantage of "growing the pie" (i.e. value creation) through multilateral coordination. This is driven by the extent that the proposed solution threatens to erode these firm-level competencies.

Discussion

The objective of our paper was to propose a conceptual framework that identifies the theoretical mechanisms behind the emergence of multifirm coordination organizations and the potential factors that affect the effectiveness of these organizations. Although our framework integrates strategy perspectives that might inform this direction of inquiry, there are two key distinctions that separate it from prior research, particularly work on coopetition, alliances and value creation/ value capture.

First and foremost, drawing on the ecosystem-as-structure perspective, multilateral interdependencies and multilateral complementarities play a crucial role in our framework. Importantly, because multilateral interdependencies cannot be easily decomposed into multiple bilateral interdependencies (Adner, 2017), and because realizing multilateral complementarities requires multiple compatible complementary components to be available, firms cannot construct piecemeal bilateral arrangements and realize a focal value proposition at the ecosystem level. These properties delineate the rationale for the multifirm technology coordination setting from the typical types of inter-organizational arrangements that have been the focus of a majority of research in the strategic alliances and in the coopetition tradition. Notably, the technological and strategic architectures of firms interact with the presence of multilateral complementarities in determining the extent to which firms converge towards multifirm coordination.

Second, and relatedly, both the value created and the value appropriated by individual firms are *endogenous* to the outcome of the coordination activity, which itself is subject to intense deliberations, negotiations and technical debate. On the one hand, specific proposals to create value by firms might promise to unlock tremendous value for the entire ecosystem while sustaining existing competencies of a majority of firms involved and allowing substantial scope for continued inter-firm differentiation. On the other hand, tensions around asymmetries in value appropriation from such proposals might undermine the collaborative efforts to create mutual value unless they can be mitigated through specific ecosystem governance mechanisms. However, the inherent uncertainty that characterizes such a coordination process tends to be beyond the scope of contract design, wherein firms could in theory have devised appropriate terms to limit future risks. Thus, while both common benefits and private benefits affect the nature of economic rents in multifirm settings analogous to other forms of coopetition (e.g. Dyer at al., 2008), the extent of influence and control of individual firms on the emerging consensus rules in multifirm settings is likely to be much more muted. However, what distinguishes such settings is that there is likely to be substantial variation in such control across different multifirm coordination arrangements depending upon the structure of the networks of firms' interconnections. This in turn has implications not only on the outcome or effectiveness of the coordination but also on the technological trajectories and entry/ exit of firms. For instance, it is plausible that coordination activity between firms that are embedded in highly centralized network structures is more susceptible to the influence of large incumbent firms that occupy central positions. On the other hand, it may force the crowding out and branching out of peripheral firms particularly if highly innovative ideas that are foundationally distant involve very high adjustment costs for existing firms (e.g. Ranganathan and Rosenkopf, 2014).

Conclusion

Akey aim of this framework is to facilitate new theoretical research directions that deepen our understanding of the formation and subsequent outcomes of multilateral technology coordination forums. In this regard, there are certainly low hanging empirical fruit offered in our frameworks. For instance,a common empirical approach that can be adapted to measuring the potential for technology licensing is through patents. Other elements of our frameworks, such as generative appropriability, represent novel opportunities in and of themselves in devising ways to assess constructs that we see as foundational to understanding multilateral technology coordination.It is also worth mentioning that formal or computational techniques may be useful towards theorizing from our frameworks. Indeed, the modularity and complementarity that are pervasive in our framework are the subject matter of computational model studies on technological innovation (e.g., Ethiraj 2004; Ganco, Kapoor and Lee 2019). Organizational structures, in a broad sense, are also prevalent in extant computational work (Siggelkow and Rivkin 2005, 2006; Rivkin and Siggelkow 2003.; Csaszar 2013).

Recent advances in machine learning techniques will also allow empirical researchers more tractability in measuring our proposed constructs such as module and component complexity, variability in technological change or variability in component criticality, using both patent citation as well as technical proposal data from these forums. Furthermore, the emphasis on transparency and openness in many large technology standards forums also allows researchers easy access to fine-grained information from these forums, including meeting minutes, voting records and other communications during inter-firm interactions and deliberations in these settings. Indeed, standard-setting forums may afford the best empirical context to propose and test theoretical mechanisms on the shaping, emergence and evolution of several digital ecosystems that have become the backbone of our modern economy.

Table 1: Bilateral vs. Multilateral coordination

Characteristic of Coopetition	**Bilateral coordination**	**Multilateral coordination**
Objective	R&D or Commercialization Sharing or combining resources	Interoperability, Compatibility, Defining system architecture Resolving technical uncertainty
Governance	Contractual – varies depending on alliance type/objective Trust and repeated exchange	Committee – equal voting rights to all participants Rule-based and technical merit Repeated interactions over multiple bodies
Nature of commitments	Quasi-irreversible	Non-binding
Length	Defined	Unbounded, iterative
Control over partner selection	Full control	No control
Control over partner behavior	High	Contingent
Nature of influence	Market power Repeated ties Alliance capability	Technical merit & consensus Network-based Multilateral negotiation capability
Value appropriation	Defined ex-ante Coopetitive threats include hazards of exchange and learning races	Apparent only ex-post Coopetitive threats include tradeoff between hazards of disclosure versus lost opportunity of non-disclosure, and adjustment costs of current resources
Value creation	Complementarities are bilateral and based on combining existing resources	Complementarities are multilateral and based on aligning existing resources to common rules and creating future resources contingent on alignment

Figure 1: Antecedents to multifirm coordination

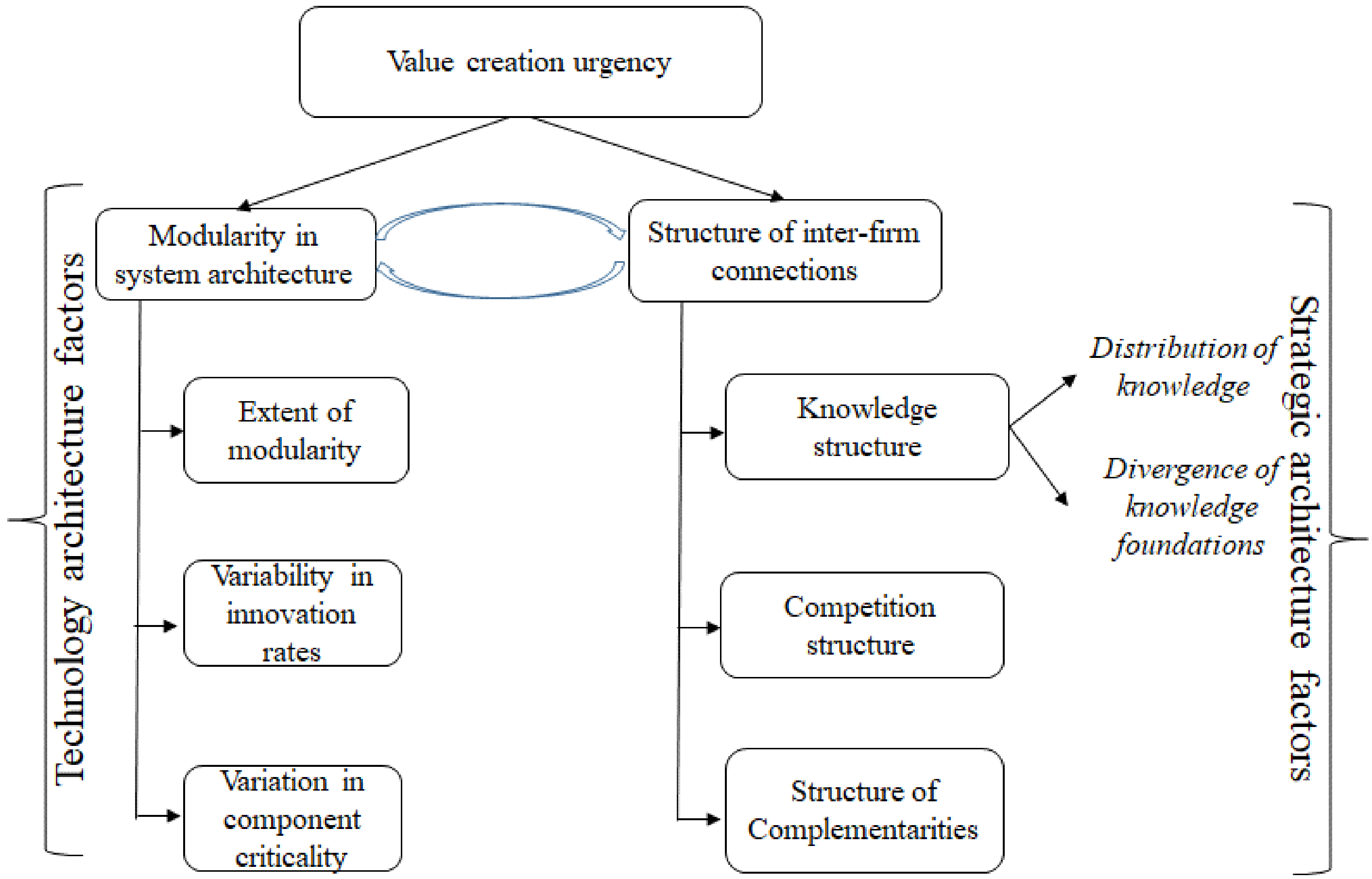
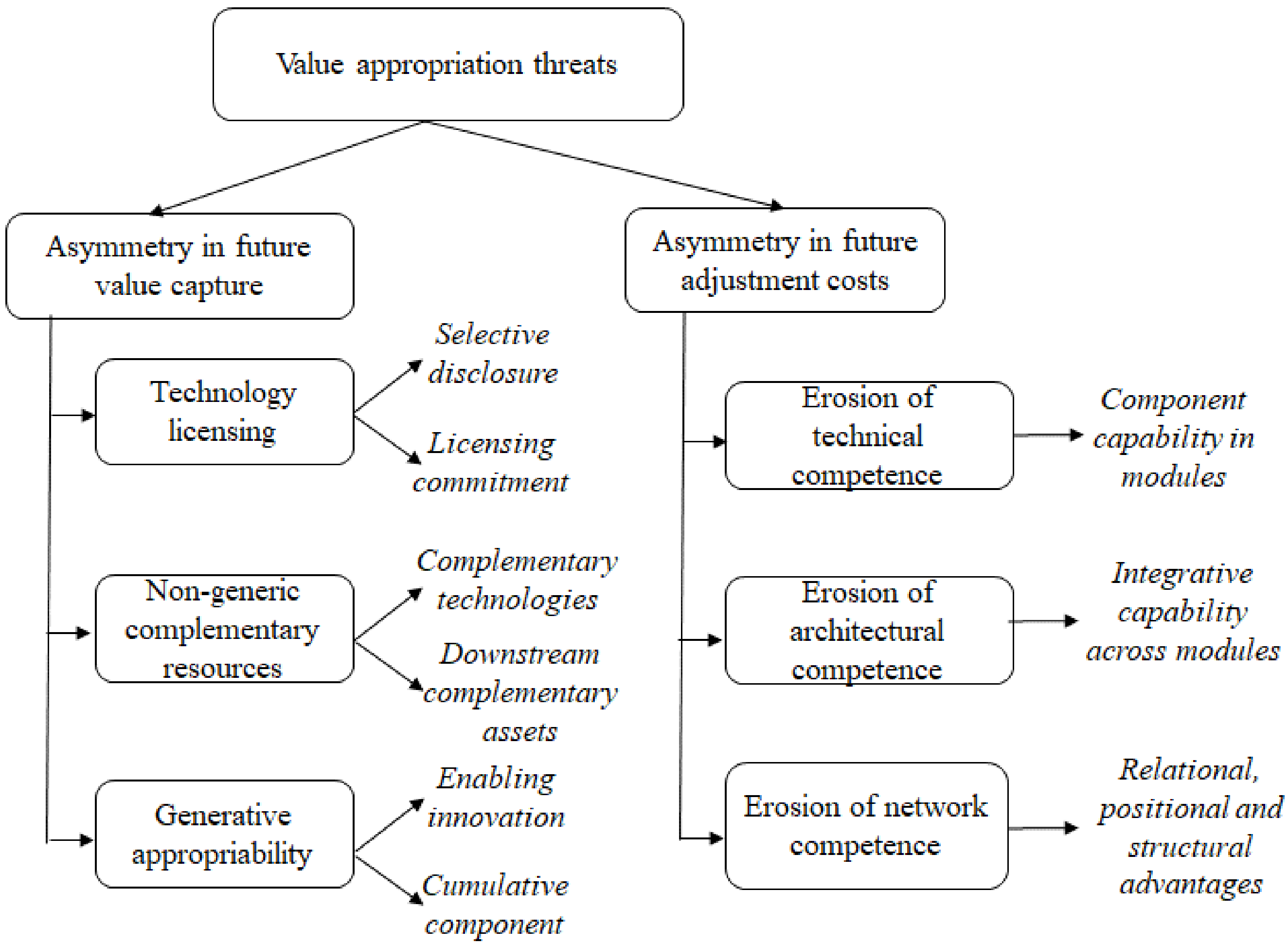


Figure2: Effectiveness of multifirm coordination



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