Towards a Theory of Ecosystems

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Michael G. Jacobides
London Business School

Carmelo Cennamo
Università commerciale Luigi Bocconi

Annabelle Gawer
University of Surrey

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Michael G. Jacobides, London Business School, *mjacobides@london.edu* *

Carmelo Cennamo, Bocconi University, *carmelo.cennamo@unibocconi.it*

Annabelle Gawer, University of Surrey, *a.gawer@surrey.ac.uk*

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Towards a Theory of Ecosystems

Abstract

The recent surge of interest in "ecosystems" in strategy research and practice has mainly focused on *what* ecosystems are and *how* they operate. We complement this literature by considering *when* and *why* ecosystems emerge, and what makes them distinct from other governance forms. We argue that modularity enables ecosystem emergence, as it allows a set of distinct yet interdependent organizations to coordinate without full hierarchical fiat. We show how ecosystems address multilateral dependences based on various types of complementarities - supermodular or unique, unidirectional or bidirectional, which determine the ecosystem's value-add. We argue that at the core of ecosystems lie *non-generic* complementarities, and the creation of sets of roles that face similar rules. We conclude with implications for mainstream strategy and suggestions for future research.

Managerial Abstract

We consider what makes ecosystems different from other business constellations, including markets, alliances or hierarchically managed supply chains. Ecosystems, we posit, are interacting organizations, enabled by modularity, not hierarchically managed, bound together by the non-redeployability of their collective investment elsewhere. Ecosystems add value as they allow managers to coordinate their multilateral dependence through sets of roles that face similar rules, thus obviating the need to enter into customized contractual agreements with each partner. We explain how different types of complementarities (unique or supermodular, generic or specific, uni- or bi-directional) shape ecosystems, and offer a "theory of ecosystems" that can explain what they are, when they emerge and why alignment occurs. Finally, we outline the critical factors affecting ecosystem emergence, evolution, and success -- or failure.

INTRODUCTION

Over the last few years, there has been a surge of interest in the concept of "ecosystems" as a new way to depict the competitive environment. Practitioners share this enthusiasm: In the 2014 prospectus for the world's largest IPO to date, Alibaba, the word "ecosystem" appears no fewer than 160 times. The term is entering the vocabulary not only of technology firms but also of more established sectors, from financial services to manufacturing (Deloitte, 2015).

Beyond practice and the popular business press, ecosystems have also been eagerly adopted in the field of strategy, with Teece (2014:1) suggesting that "the concept of ecosystem might now substitute for the industry for performing analysis." While ecosystems have been considered in our field for some time (Dhanaraj & Parkhe, 2006; Iansiti & Levien, 2004; Moore, 1993), the last few years have seen a boom. Searching the keyword "ecosystem" in the title or abstract of the top strategy journals shows that its frequency has increased sevenfold over the last five years.

Unarguably, this research has articulated some important competitive, collaborative, and organizational challenges faced by firms. Adner (2017) offers a view on how ecosystem research relates to established views, and offers a useful guide to the differences in phenomenological emphasis between ecosystem research and other streams. This paper takes a step further, synthesizing existing research to elucidate the key mechanisms behind the emergence and dynamics of ecosystems, and *why* we have seen such a rise in interest. As a first step toward a positive theory, we consider the conditions necessary for ecosystems to emerge—modularity in particular—and the interactions that make them interesting—specifically, the coexistence of different *types* of complementarities. We further argue that examining the nature, directionality, and intensity of these complementarities, and what firms do to influence them, thus shaping ecosystem formation and structure, can help explain the distinct value creation and capture dynamics within and between ecosystems.

Our objective is to complement the literature's interest in what ecosystems *are*, by analyzing *how* and *why* they differ from other phenomena, and by clarifying what unique mechanisms they have for value creation and value capture. We reflect on when we might expect to see ecosystems displace traditional market-based arrangements or vertically integrated supply chains. We propose that ecosystems are distinct forms of organizing economic activities that are linked by specific types of complementarities. We also sharpen the distinction between the *structures* of ecosystems and the *behaviors* they give rise to, building on the fundamental distinctions between different types of complementarities to create clearly distinct sets of ecosystems, with particular strategic dynamics. We conclude with the resulting research agenda.

THEORETICAL BACKGROUND AND THE GROWTH OF ECOSYSTEMS

Borrowed from biology, the term "ecosystem" generally refers to a group of interacting firms that depend on each other's activities. Scholars have emphasized different aspects of an ecosystem depending on the unit of analysis. In reviewing the literature, we identified three broad groups of papers:[1] a "business ecosystem" stream, which centers on a firm and its environment; an "innovation ecosystem" stream, focused around a particular innovation or new value proposition and the constellation of actors that support it; and a "platform ecosystem" stream, which considers how actors organize around a platform.

[1] Our literature review consisted of looking at all papers with "ecosystem" in their title and abstract, published in the top management journals. Having read them, we created three tentative categories. These categories were refined, and further validated, by textual analysis (available upon request) using NVivo, which confirmed the existence of different themes and topic emphases in each of these three streams. While these categories are not meant to be mutually exclusive and collectively exhaustive, the exercise did help create groupings, which were further validated by asking a research assistant to assign papers into each of the categories reported in the text.

The first stream focuses on an individual firm or new venture[2], and views the ecosystem as a "community of organizations, institutions, and individuals that impact the enterprise and the enterprise's customers and supplies" (Teece, 2007: 1325). Here, the ecosystem is conceived as an economic community of interacting actors that all affect each other through their activities, considering all relevant actors beyond the boundaries of a single industry. For Teece (2007), the ecosystem represents the environment that the firm must monitor and react to, which affects its dynamic capabilities and thus its ability to build sustainable competitive advantage. Others stress the "shared fate" of the community as a whole (Iansiti & Levien, 2004: 69)—individual members' performance is tied to the overall performance of the ecosystem. Despite the emphasis on co-evolution of firm capabilities, there is little explanation of how firms mutually adapt. Authors such as Iansiti and Levien (2004) stress the role of ecosystem managers—"hub" or "keystone" firms—as the providers of stability. As Dhanaraj and Parkhe (2006) argue, hub firms manage knowledge mobility, innovation appropriability, and network stability. These mechanisms have rarely been studied (for exceptions, see Azzam *et al.*, 2016 or Pellinen *et al.*, 2012) and empirical support remains limited even within these studies.

The second set of studies focuses on a focal innovation and the set of components (upstream) and complements (downstream) that support it, and views the ecosystem as "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" (Adner, 2006: 98). The emphasis is on understanding how interdependent players interact to create and commercialize innovations that benefit the end customer—with the corollary that if coordination within the ecosystem is inadequate,

[2] Studies focusing specifically on new ventures tend to see the ecosystem as a location-specific cluster of firms, entities, and individuals; consider the new venture as the unit of interest of the analysis; and focus on new venture creation and related entrepreneurial issues, including knowledge/innovation spillovers, growth, access to resources, and markets (e.g., McGregor & Madsen, 2013; Pitelis, 2012; Zahra & Nambisan, 2012; Zacharakis *et al*., 2003). Empirical studies in this area have mainly examined start-ups in internet, high-tech, and ICT sectors.

innovations will fail (e.g., Adner & Kapoor, 2010; Adner, 2012; Kapoor & Lee, 2013). Here, the anchoring point is the system of innovations that allows customers to use the end product, rather than the firm. Accordingly, the ecosystem concept is intended to capture the link between a core product, its components, and its complementary products/services ("complements"), which jointly add value for customers. The firm(s) producing the focal innovation may or may not be directly connected to complement providers ("complementors"); the extent to which firms align through different arrangements will affect their capacity to create value for the end customer (Adner 2017). Here, the ecosystem casts a net around the "virtual network[s]" (Iyer *et al*., 2006) or "complex entities of group-related actors" (Brusoni & Prencipe, 2013) that offer focal and complementary innovations. Research has considered how different collaborative arrangements between the innovator and its complementors affect both groups' ability to coordinate investments into a new technology and its commercialization (e.g., Kapoor & Lee, 2013; Leten *et al*., 2013); how knowledge sharing affects the strength of inter-firm relationships and thus the development of the ecosystem (e.g., Alexy *et al*., 2013; Brusoni & Prencipe, 2013; Frankort, 2013); or the health and survival of the ecosystem (Leten *et al*., 2013; West & Wood, 2013).

The third set of studies focuses on a specific class of technologies—platforms—and the interdependence between platform sponsors and their complementors. In this view, the ecosystem comprises the platform's sponsor plus all providers of complements that make the platform more valuable to consumers (Ceccagnoli *et al*., 2012: 263; Gawer & Cusumano, 2008: 28)[3]. The platform ecosystem takes a "hub and spoke" form, with an array of peripheral firms connected to the central platform via shared or open-source technologies and/or

[3] The platform concept has gained extensive traction in its own right, spurring a whole literature looking at the peculiar network-externality dynamics characterizing so-called "platform two-sided markets" (e.g., Hagiu, 2006; Parker & Van Alstyne, 2005; Rochet & Tirole, 2003). While we explicitly considered the platform in relation to the ecosystem of specialized complementary goods/services, a broader review is outside this paper's scope.

technical standards (which, for IT-related platforms, can be programming interfaces or software development kits). By connecting to the platform, complementors can not only generate complementary innovation, but also gain access, directly or indirectly, to the platform's customers—as in the examples of independent software vendors affiliating to SAP (Ceccagnoli *et al.*, 2012) or developers producing videogames for specific consoles (Cennamo & Santaló, 2013). Accordingly, platform ecosystems are seen as "semi-regulated marketplaces" that foster entrepreneurial action under the coordination and direction of the platform sponsor (Wareham *et al.*, 2014: 1211), or as "multisided markets" enabling transactions between distinct groups of users (Cennamo & Santaló, 2013).[4] See McIntyre and Srinivasan (2017) for a recent critical review.

Ecosystems as new structures of economic relationships. While these views might reflect differences in research focus, they emphasize aspects of the ecosystem that overlap in the real world. It is broadly agreed that ecosystems require providers of complementary innovations, products, or services, who might belong to different industries and need not be bound by contractual arrangements—but have significant interdependence nonetheless. In this sense, ecosystems do not fit into the classical firm-supplier relationship, Porter's (1980) value system, or a firm's strategic networks; neither are they integrated hierarchies.

Studies taking the firm as the unit of interest consider the ecosystem to include the ties that the firm has to the actors that affect, or are affected by, its activities. Those taking the *innovation* as the unit of interest have considered interconnected innovations upstream (i.e., components)

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[4] Despite the greater consistency among ecosystem platform scholars, they still vary in terms of the elements posited as constituting an ecosystem. While some studies examine platforms as means for complementors to access customers (e.g., Ceccagnoli *et al.*, 2012; Cennamo & Santaló, 2013; Cennamo, 2016; Wareham *et al.*, 2014), others focus more on technology evolution through the interaction between the platform owner and its complementors, and in relation to competing ecosystems, but do not regard final customers as central to such dynamics (e.g., Gawer & Cusumano, 2002; Gawer & Henderson, 2007).

and downstream (i.e., complements) in the same industry (e.g., Adner & Kapoor, 2010; Frankort, 2013), connections running through sub-industries (e.g., Makinen & Dedehayir, 2013), firm-complementor dyads (e.g., Kapoor & Lee, 2013), or multi-party collaboration (e.g., Leten *et al*., 2013; West & Wood, 2013). Studies on platform-based ecosystems have considered connections between the platform sponsor and its complementors (Ceccagnoli *et al*., 2012; Cennamo & Santaló, 2013; Gawer & Henderson, 2007) established through standards and platform interfaces (Gawer 2014), the leadership role of the platform at the industry level (e.g., Gawer & Cusumano, 2002), the impact of the platform's technological complexity on complementors' innovation capacity (e.g., Kapoor & Agarwal 2017), or rivalries between competing platform ecosystems (e.g., Cennamo & Santaló, 2013).

Most studies consider deliberate intent of specific actors to be important, and focus on the role of the hub—dubbed the "lead firm" (Williamson & De Meyer, 2012), "keystone" organization (Iansiti & Levien, 2004), or "ecosystem captain" (Teece, 2014)—in shaping the emergence of an ecosystem (Moore 1993, Teece, 2007). According to Gulati *et al.* (2012), the presence of an "architect," who sets a system-level goal, defines the hierarchical differentiation of members' roles, and establishes standards and interfaces, is an essential and distinguishing feature of an ecosystem (also see Teece, 2014).[5] Studies tend to concur that ecosystems are not hierarchically managed, but few have specifically looked at the rules governing membership and relationships. Gulati *et al.* (2012) consider ecosystem membership to be "open"—i.e., not granted bilaterally between hub and prospective member, but based on self-selection. However, recent work paints a more nuanced picture, suggesting that formal mechanisms, including the management of standards and interfaces (Baldwin, 2012; Teece,

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[5] Some contend that the hub is not necessarily the largest or most resource-rich member of the ecosystem, but rather the one that uses "smart power" (Williamson & De Meyer, 2012), "problem framing" (Brusoni & Prencipe, 2013), or "informal authority" based on knowledge, status, or control over key resources or technology (Gulati et al., 2012). Also see Gawer and Phillips (2013) on "institutional work."

2014), platform governance (Cennamo & Santaló, 2013; Wareham *et al*., 2014), or intellectual property rights and other contractual forums, are key tools that hubs use to discipline and motivate ecosystem members (Alexy *et al*, 2013; Brusoni & Prencipe, 2013; Leten *et al*, 2013; Ritala *et al.*, 2013).

Research in the platform ecosystem tradition also considers how technological interfaces (and which parts of the technology are "open" or "closed") or governance (such as membership and participation rules) shape collective outcomes (Ceccagnoli *et al*., 2012; Cennamo, 2016; Gawer & Cusumano, 2002; Gawer, 2014; Wareham *et al*., 2014). Balancing the trade-offs involved in controlling the core technology is one of the main goals of platform ecosystem governance (Cennamo & Santaló, 2013; Cennamo, 2016; Wareham *et al.*, 2014), also identified as a key problem of organization design (Baldwin, 2008; 2012).

An effort to consolidate progress, and questions still unanswered. Clearly, ecosystem research has not grown in isolation from the mainstream literature. Yet it is characterized by a heavy emphasis on what is distinctive or novel about ecosystems. Only a handful of studies have explicitly tried to bridge existing perspectives (e.g., network analysis; alliance research) and ecosystems; even then, they have taken "ecosystems" as a given and examined them from the perspective of a given theory. Venkatraman and Lee (2004) and Iyer et al. (2006), for instance, have taken a "central" firm, in the network sense, to be the hub in an ecosystem. While this yields an interesting map, there is less attention on how the extra complexity added by the ecosystem terminology provides fresh insights. Likewise, Texeira et al. (2015) consider network densities and collaboration in ecosystems, but don't focus on what we learn from the fact that ecosystems do have network structures. McIntyre and Srinivasan (2017) provide a thorough and critical overview of platform and network-related ecosystems, articulating questions to be considered by future research and linking with earlier work.

An important contribution here is made by Adner (2017), who proposes that "the ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize" (2017: 42). "Alignment structure," defined as "the extent to which there is mutual agreement among the members regarding positions and flows," becomes the objective, pursued through a firm's "ecosystem strategy" to "secure its role in a competitive ecosystem" (2017: 47).

Taken together, prior research leaves open intriguing questions regarding the factors that make ecosystems—as opposed to integrated supply chains or arm's-length relationships—"increasingly critical" (Adner 2017: 53); the factors that enable (or inhibit) alignment via an ecosystem; and what ecosystem thinking can tell us that other literature streams cannot. The remainder of this paper offers some proposals in this direction and identifies the key contingencies that shape different *types* of ecosystems.

TOWARDS A THEORY OF BUSINESS ECOSYSTEMS

Theoretical primers: modularity and coordination in ecosystems. An important but neglected characteristic of ecosystems is that they help coordinate interrelated organizations that have significant autonomy. In nearly all the empirical cases we know of (from both literature and experience), this is enabled by a modular architecture (Baldwin & Clark, 2000), where the distinct parts of the ecosystem represent organizations that are separated by "thin crossing points" (Baldwin, 2008), i.e. discrete parts of the production process. Technological modularity allows interdependent components of a system to be produced by different producers, with limited coordination required. While the overarching architecture design parameters may be set by a hub, organizations have a large degree of autonomy in how they design, price, and operate their respective modules, as long as they interconnect with others in agreed and predefined ways.[6] While new coordination issues always arise, ecosystems provide processes and rules on how to resolve them, and encourage alignment through rules of engagement, standards, and codified interfaces. The presence of modularity is also the condition that allows a hub to forego at least some degree of explicit coordination. Thus, modularity (though not necessarily open interoperability) creates the conditions for an ecosystem to emerge.[7]

More modularization has been associated with a greater prevalence of ecosystems in a number of sectors, from telecommunications to financial services to mobility. Many of the sectors that have been studied in the context of ecosystems—IT, telecommunications, videogames, etc.—tend to be more modular, suggesting that ecosystems may well be a distinct solution to the problem of inter-firm coordination, distinct from the use of alliances, supply-chains or market-based interactions. So, we posit that modularity allows for coordination of independent yet interdependent firms through ecosystems. Yet while modularity may be necessary for ecosystems to function, it is clearly not sufficient. As Baldwin (2008), Langlois (2003), and Jacobides & Winter (2005) argue, modularization and the subsequent reduction of frictional transaction costs is more likely to lead to the emergence of *markets*. For ecosystems to be useful, there must also exist a significant need for coordination that cannot be dealt with in markets, but which also does not require the fiat and authority structure of a central actor.

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[6] In most ecosystems, firms (e.g. app producers for iOS) are able to set the price and freely decide content of their products, even if there is a set of clear specs. In others, such as Uber, drivers can set their desired availability, and choose the quality they offer (which affects rider reviews and thus demand), and price can vary—albeit uniformly for all drivers in an area. All these independent yet interdependent structures entail *some* modularity.

[7] It is important here to distinguish between modularity as we define it and its more colloquial uses. Modularity is here meant to denote the separability along a production (or production and consumption) chain. This does not entail "plug and play" interoperability and free entry. Conditions of participation in each module or part of the ecosystem may be exclusive. For instance, Apple may have a modular system, but part of it is open only to parts of its own organization; parts of it are open to suppliers; parts of it are open (with stringent criteria) to complementors; and parts of it are open with few restrictions. Modularity does not necessarily entail openness.

This, in turn, arises due to different types of complementarities.

Ecosystems, we posit, are distinctive both because of their structure, and because of the way in which they allow the coordination challenge to be resolved. Figure 1 below illustrates how ecosystems differ in terms of structure, when compared to either market-based transactions or supplier-mediated arrangements (including those through a system integrator, or an integrated firm). What sets them apart from an aggregate of buyer-supplier relations is that in ecosystems final customers can choose among the components (or elements of offering) that are supplied by each participant, and can also, in some cases, choose how they are combined. For example, the end user in the Android phones ecosystem decides which apps they buy, and from which provider, instead of buying a single, combined offering ("as is") provided by a single firm. What sets ecosystems apart from market-based arrangements is that end customers choose from a set of producers or complementors who are bound together through some interdependencies—by all adhering to certain standards, for instance. In this sense, ecosystems differ from networks (Powell, 2003), and represent webs of *standardized* formal or informal alliances between participants, where, e.g., complementors can choose from a set menu of options and are treated similarly. In ecosystems, even customers themselves must "affiliate" (Hagiu and Wright 2015) with one group or platform to be able to use its specific complements like in the case of apps. But what distinguishes this group of "affiliated" participants, and what is so different about ecosystem-mediated complementarities? To understand this, we must first briefly consider the various types of complementarities in economic relationships.

Types of complementarity: understanding what underpins ecosystems. As Teece (2017: 17) notes, "the literature on complements is both confused and complex."[8] For our purposes, we focus on two types of complementarities that can be expressed unambiguously in mathematical terms, and characterize relationships between actors within ecosystems.

First, we have unique complementarities. The strict version is that "A doesn't "function" without B," where A and B can be specific items—like the two ends of a pipeline (see Hart & Moore, 1990)—steps, or activities. The more general version is that the value of A is maximized with B (as opposed to B'). Such complementarity may also be a matter of degree, with a continuum extending from strict or strong (where A requires B) to specific (where A requires B to be customized to it to be productive) to generic.[9] Unique complementarity can be one-way: Activity or component A requires a particular (asset-specific) activity or component B[10], but not vice versa. Or it can be two-way, where A and B both require each other, which is what underpins the idea of *co-specialization* (Teece, 1986).[11]

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[8] Teece suggests that Samuelson's quote (1974: 1255) that "the time is ripe for a fresh, modern look at the concept of complementarity … this ancient preoccupation of literary and mathematical economists. The simplest things are often the most complicated to understand fully" is still relevant today. We concur.

[9] Hart & Moore's (1990) definition of unique (strict) complementarity implies that the two assets are unproductive unless they are used together, which makes coordination of investments in the two assets critical to maximize the marginal return on investment.

[10] By A "needs" B, here we mean: the use of A and B together will help achieve the system's overall purpose. Note that most of the theory, especially transaction cost economics (TCE), considers that we can substitute activities and components that are not specialized—using C rather than B—and the result will still be functional, albeit less efficient. This trade-off between efficiency and the risks of specificity underpins TCE.

[11] To put this in theoretical context, TCE focuses on unique complementarities that arise as a result of asset specificity, which itself is a managerial choice, requiring the appropriate governance choices to protect against attendant behavioral risks (Argyres & Zenger, 2012; Williamson, 1985). As such, unique complementarity that arises because of asset specificity makes integration attractive. TCE focuses on unique complementarity in production, though there can be unique complementarity in use, where a consumer needs to "assemble" different components that only work together.

However, as Teece (1986) observed, complementarities may also be generic. That is, while a particular good or service may be needed for the production of a complex value proposition or innovation, that good or service may be generic (i.e., standardized) enough for firms to draw on it with little concern for governance structure or risks of misappropriation. The use of generic complements, discussed in detail by Helfat & Lieberman (2002), is an important and common way to facilitate production while safeguarding against contractual hazards. The same principle applies for an ecosystem analysis. To illustrate, electricity is needed for almost everything, but the fact that it can be purchased in generic terms means that this complementarity does not give rise to particular issues of economic organization[12], and as such, it can take place in markets instead (Adner, 2017). In other words, the generic nature of this complement means that there is no need to coordinate in specific ways (i.e., no need to create a specific alignment structure) between the economic actors. A teacup, boiling water, and a tea bag may all be needed to make a cup of tea, but the complementarities are generic, not specific. While consumers derive utility by combining these elements into a "product system" (i.e., a cup of tea), producers do not need to coordinate their investments through structures to enable such value. Consumers can thus buy them separately in the market and combine them on their own. This is *not* to say that generic complements are not relevant for economic actors; it is to say that generic complementarities have a different impact, understood elsewhere (e.g., Rosenberg, 1969), and require no special new label.

The second category of complementarity we consider is supermodular or "Edgeworth" complementarity. This concept has been developed by Milgrom and Roberts (1990), building

[12] This highlights the key point that assets that are more fungible across applications along a production (and consumption) chain are generic in nature (see Helfat & Lieberman, 2002 for an extended discussion.)

on Topkis (1978; 1998) and can be summarized as "more of A makes B more valuable," where A and B are two different products, assets, or activities.[13] It can be found in both production and in consumption. In production, it is manifested when coordinated investments in both A and B yield higher returns than uncoordinated equivalents, or yield lower costs than the sum of costs of independent investments into A and B (e.g., Arora & Gambardella, 1990; Cassiman & Veugelers, 2006; Lee *et al.*, 2010). Supermodularity in consumption, more commonly associated with Edgeworth, is famously the basis of both direct and indirect network effects (e.g., Farrell & Saloner, 1985; Parker & Van Alstyne, 2005)[14], and can be one-way or two-way. These different types of complementarities may also coexist. In the example of an OS platform/app ecosystem, the app and the platform have a unique complementarity in the sense that the app does not function without the OS (unique complementarity, unidirectional, as the OS operates without most apps); and supermodular complementarity, as the presence of apps increases the value of the OS, and (possibly) the breadth of the OS installation increases the value of the app.

While there are additional ways to organize our understanding of complementarities,[15] the

[13] There is a long history of this type of complementarity, starting with F.Y. Edgeworth, who considered it in the context of consumption of goods—looking at how changes in demand of one affects the demand of another (see Samuelson, 1974, for a more recent analytical treatment and Weber, 2005, for a historical account). Milgrom and Roberts shifted the analysis, and popularized Topkis, using lattice theory, and employing complementarities less on consumption, than on production—with their quintessential example being the Japanese production system, where the value of one practice depends on the existence of another, per the analytics of Topkis (1978). This is why we use the formal term "supercomplementarity." To provide the analytical definition, Milgrom and Roberts (1994: 6) note that "a group of activities are (Edgeworth) complements if doing more of any subset of them increases the returns to doing more of any subset of the remaining activities."

[14] Direct network effects emerge when consumers value the fact that other consumers use a particular product or service- like in the case of users of a fax machine. Indirect network effects occur when the existence of a variety of complements creates value to other complements- suggesting that some final customer values variety (not volume).

[15] Teece (2017), for instance, considers a different set of complementarities, which include some we don't consider, such as *Hicksian complements,* "when a decrease in the price of one factor leads to an increase in the quantity used of its complements in production", or *Hirshleifer (Asset Price) Complementarity* to denote how innovation in one segment affects asset prices in another. He also considers *technological* complementarities,

discussion of these two types, and of their different directions, gives us our foundation here. These complementarities can apply to both production and consumption.

As we define them, then, ecosystems are *groups* of firms that must deal with either unique or supermodular complementarities that are *non-generic,* requiring the creation of a specific structure of relationships and alignment to create value. The strength of ecosystems, and their distinctive feature, is that they provide a structure within which complementarities (of all types) in production and/or consumption can be contained and coordinated without the need for vertical integration.[16] From this perspective, ecosystems allow for some degree of coordination without requiring hierarchical governance, precisely because of the ability to use some standards or base requirements that allow complementors to make their own decisions (in terms of design, prices, etc.), while still allowing for a complex interdependent product or service to be produced.

Ecosystems as the result of a (partly designed) process. Ecosystems, of course, do not just "emerge" spontaneously. They are at least in part the result of deliberate experimentation and engineering from different parties. For instance, a firm may choose to modularize a process, or may opt not to procure generic complements available on the market not only because non-fungibility may give it additional design options, but *because* it wants to set up an ecosystem to create or extract more value. Overall, powerful firms (especially hubs, or hub contenders) craft rules and shape the process of ecosystem development to tie in complements and make

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which occur when "the full benefit (or even any benefit) of the innovation cannot be achieved until some other, complementary technology (which, on its own, has only lower value uses) has been created or re-engineered"—a condition that we consider to be very frequent in the settings covered by ecosystems, and as such encompassed by either of our proposed categories.

[16] Adner and Kapoor (2010) intriguingly find that the role of upstream complements differs from the role of downstream complements, when we consider their impact on ecosystem health. This arises, we would argue, from the fundamentally different role of unique complementarity (dominant in production) from Edgeworth/supermodular complementarity (dominant in consumption, i.e. downstream).

complementors abide to them. To give a specific example, even within the Google/Android ecosystem, with Google as the hub and clear rules for complementors, some key handset manufacturers such as Samsung and Motorola are starting to create sub-ecosystems. They allow key app developers to connect via APIs in ways that are specific to their device, so as to "lock them in" with non-fungible investments.

Ecosystem design is becoming ever more important as the question of what drives customer value, and how firms can capture this value by *monetizing it* in some way, becomes an open question in a technologically mediated world, where regulation provides some loose contours of how sectors can work and what actors can legitimately sell (Parker, Van Alstyne, and Jiang, 2016). Firms identify what drives value to users (B2C), but do not always charge the users for it; often they charge other clients (B2B), who are willing to fund a venture to acquire its client information or access, or to show that they are affiliated with value-adding services (B2B2C). This requires the formation of ecosystems, where rules and roles, and monetization, as well as how players are connected, become an essential part of the business model design.[17]

Finally, while modularity, the nature of complementarities, and fungibility may all be partly designed, the process is not always driven by foresight. Some firms—especially those who allow modular technologies—may *unwittingly* form ecosystems. Arguably, this happened to inkjet printer makers, who faced entry by unauthorized ink-cartridge producers. More famous,

[17] Consider Traipse, an app providing a geo-located "treasure hunt" experience via smartphones, which serves the dedicated group of puzzle-solvers who also like to engage with and explore local communities. Its B2C technology allows individuals to challenge themselves in tours of historic districts as they solve riddles. Most of its revenues come from B2B Chambers of Commerce or tourist bureaus that want to promote their local shops and sights to this dynamic demographic, that fund the cost of developing tours; local businesses also fund the venture by offering "prizes" as discounts in their stores, potentially giving a commission to Traipse for each sale. Traipse also uses a cryptocurrency which is used as an *exchange* means and creates local stickiness, based on smartoken.com—yet another venture which is B2B and connects with businesses giving it commissions for creating its blockchain technology to power localized ways of exchanging funds. So user and client are distinct in such models.

when hackers developed the first apps for Apple's iOS, they wound up in court—until Steve Jobs realized he could turn an *unwitting* ecosystem into a *regulated* one, and profit from it.

Characteristics of ecosystems. To understand how ecosystems operate, we first need to fully define them. We do so by drawing on pragmatism (see James, 1975; Dewey et al., 1999).[18] Our approach differs from existing ones by focusing on the nature of complementarities between ecosystem participants, and the fungibility of their investments, as opposed to the resulting collaborative (or alignment) structures. It is motivated by the desire to focus on the mechanisms that result from complementarity type, and also by our desire to avoid issues that, while potentially important, have been addressed by prior work.[19] Concretely, we suggest that:

> An ecosystem is *a set of actors with varying degrees of multi-lateral, non-generic complementarities that are not fully hierarchically controlled.*

This encapsulates three crucial attributes of an ecosystem. First, "multi-lateral, non-generic complementarities" are either unique complementarities (which essentially lead to some degree of co-specialization), or supermodular/Edgeworth complementarities (often found in complements-in-use). Our narrow definition delimits the scope of the ecosystem to *specific* complements. So, while boiling water may complement tea bags and teacups, they are *generic* complements in consumption and thus are not parts of an "ecosystem" by our definition. We exclude generic complementarities because they do not give the parties any vested interest to align and act as a group. While any focal actor would do well to consider *all* its

[18] That is, we do not start from the realist premise that there is "some" truth about ecosystems in the world, which we try to approximate, but rather view constructs as vehicles to understand the world in a pragmatic sense, judged by their usefulness in helping us do so.

[19] We do appreciate the potential merit and utility of definitions that also include generic complementarities. Indeed, an inclusive approach may be the most appropriate way to go, if our intent is to warn managers against underestimating the role of external alignment when delivering an interdependent value proposition or launching an innovation, for instance (Adner, 2012, 2017).

complementarities, we do not think that generic complementarities can usefully capture what is unique about an ecosystem. This uniqueness, we argue, lies in the non-generic nature of complementarities, which also *entails some degree of customization*. It is precisely this attribute that underpins the particularities of ecosystems.

We also posit that the ("multi-lateral") complementarities exist at the level of the *sets of roles* (Adner, 2017) that link the different parties together—e.g., hub(s), suppliers, or different types of complementors. What makes ecosystems unique is that the interdependencies tend to be *standardized within each role*, which creates the need for a new set of skills in terms of designing ecosystems (Helfat and Raubitschek 2018).[20] Thus, some of the relationships between *sets* of actors will be unique, some supermodular, some generic, and others specific. But, regardless, the relations can be described at the level of the *roles* or *groups of actors* as opposed to the dyad, which is a fundamental shift from the usual mode of analysis—e.g. in TCE (Williamson, 1985). While the arrangements entered in by ecosystem members might be seen as webs of alliances, these are *standardized and set for each role* in an ecosystem.

Our analysis also makes headway in extending the useful notion of co-specialization (Teece, 1986, 2017) to explore the *nature* of mutual dependencies. These depend on the relative fungibility of investments to operate in ecosystems, and relationships within them. They define the cost to "re-tool" and "re-customize," pitted against the benefit that ecosystems bring. For unique dependencies, the benefit is the creation of a dedicated set of partners who can fulfill the requirements needed and supply, or buy, what is offered. Thus, members of

[20] For instance, all apps in the Android or iOS ecosystems are treated identically, and the interdependencies are not between Apple and its millions of app developers individually, but across the group as a whole. That said, the nature and definition of each role, as well as the conditions they are faced with is a matter of strategic (research) design. That creates the need for a new set of skills in terms of designing ecosystems, which may parallel what has been called for by Helfat and Raubitschek (2018).

ecosystems, rather than being stuck in individual sets of relationships, each fraught with their own risks, can benefit from a greater set of options. For supermodular complementarities, the benefit also comes from the value for actor X from the additional availability of input or complement Y.[21]

This analysis presents a different canon to the one used in TCE, which is based on the issues of risk mitigation in a dyadic relationship. The focus here is on how to maximize the benefits by engaging (or being part of) a *group* of firms with complementary roles, or how to design the best ecosystem structure (which will vary depending whose perspective we take). Unlike in supply relationships explored by TCE, in ecosystems, neither prices nor qualities are fixed; they are left to vary, and to be chosen (by design!) as a function of the choice of a final user, and often the objective is to coalesce with other firms in securing more final users and customers for the group.

Because of the complementarities, connecting to an ecosystem involves *some* investment that is *not fully fungible*—that is, the investment, or assets in place, cannot be easily redeployed elsewhere without cost. This cost may derive from product/offering configuration adjustments (e.g., Kapoor and Agarwal, 2017) that require new investments, adjustments to the membership and transaction rules of other ecosystems (e.g., Claussen et al. 2013), or coordination costs with other members' activities. This is, in our view, a fundamental structural feature that makes within- and across-ecosystem interactions strategically distinct. The degree to which a participant's effort is tied to one ecosystem, and cannot be recoupled in *any* other setting, determines the economic basis of their attachment to that ecosystem (see

[21] This, however, is not symmetrical between two parties; it may be that the marginal value of X increases in Y but this doesn't mean that the marginal value of Y increases in X. Also, the benefits of supermodularity are not exogenously driven: They will vary, and may decline, e.g., as the ecosystem grows and the benefit of more X goes down due to saturation.

e.g., Cennamo, Ozalp and Kretschmer 2018).

More broadly, we argue that the nature and direction of the dependencies; the extent of the underlying complementarity; and the question of whether they are unique, supermodular, or both, as well as the fungibility of investments to participate all become important *descriptors* of an ecosystem that can help us understand *when* and *why* alignment occurs—or fails. By looking at the nature of complementarities, and describing whether they happen for consumption or production, we arrive at different types of ecosystems. Figure 2 illustrates and provides real-world examples of different types of ecosystems—including producer- and platform-based ecosystems and multi-sided platforms. [22]

Insert Figures 1 and 2 about here

Finally, our definition suggests that ecosystems are not unilaterally hierarchically *controlled*. For all the power a hub (if there is one) may wield, ecosystems, as we define them here, lack the hierarchical controls of traditional firm groupings, quasi-captive systems such as *Keiretsus* or *Chaebols,* or supply networks. What we think is analytically distinct in ecosystems is that their members all retain residual control and claims over their assets: no one party can unilaterally set the terms for, e.g., prices and quantities, in addition to standards. That is, we posit that ecosystems need to be both *de jure* and *de facto* run with decision-making processes

[22] Multi-sided platforms ("MSPs") (e.g., Hagiu, 2006; Hagiu and Wright, 2015; Parker and Van Alstyne, 2005), i.e. marketplaces such as Amazon Marketplace (ecommerce marketplace), Match.com (online dating marketplace), or Just Eat (takeaway food marketplace), may create their own ecosystems. In our view, a number of MSPs are not necessarily, in and of themselves, ecosystems, inasmuch as they do not require any non-fungible investment and require *only generic* supermodular complementarity. (Some, of course, require affiliation that does lead to a type of non-fungible relational investment). Platform hubs, to be able to strengthen their position, may choose to require some complementors to invest in non-fungible ways. For instance, the way a product is promoted, sold and shipped to the final customer through Amazon Marketplace becomes unique to the Amazon marketplace and different than in other two-sided markets *to the extent that* providers *specialize* into the specific interface requirements of Amazon (e.g., Amazon's product stocking and shipping requirements that align with "Amazon Prime" service). Thus Amazon has an MSP that sustains an ecosystem with Amazon at its core.

that are *to some extent* distributed, and without *all* decisions (especially on both prices and quantities) being hierarchically set—even though standards, rules, and interfaces are often set by a "hub."[23] This allows us to distinguish between ecosystems and supply chains, since in supply chains the hub (OEM, or buying firm) has hierarchical control—not by owning its suppliers, but by fully determining what is supplied and at what cost.[24]

THEORY IMPLICATIONS: A RESEARCH AGENDA ON ECOSYSTEM DYNAMICS

Our approach complements existing research by moving beyond the description of *how* players align to consider *why* and *when* they align; it also offers a set of predictions of when ecosystems, as opposed to vertically integrated firms or supply networks, will dominate. Our focus on different types of complementarity, as they interact with modularity to drive ecosystem dynamics, can deepen and extend existing and emerging work on coordination, collaboration, and value creation/capture.

Ecosystem coordination. We posited that modularity is a critical facilitator of ecosystem emergence. This leads to a straightforward empirical prediction, which can be tested by longitudinal, within-industry or cross-industry research linking changes in modularization with the emergence and growth of ecosystems. Yet while modularity helps generate ecosystems, it is not an exogenous factor. It results from the agency of key industry

[23] There is significant variance in terms of how open and democratic rule-setting is, especially with regards to standards and interfaces used. These vary from ecosystems like Apple's, with interfaces that are strictly and fully controlled, to Linux, with the involvement of various ecosystem participants. We return to this later.

[24] Thus Toyota, which is at the center of a group of co-dependent suppliers that occupy different parts of the value chain and co-specialize with it (Nishiguchi, 1994), unilaterally decides what it will procure, from whom, and at what cost. Toyota is not, by our definition, the keystone of an ecosystem. Apple, on the other hand, with its App Store, is a keystone. It manages participation criteria, standards, and rules, which define to a great extent the type of members that participate in the ecosystem, and how they interact, but does not decide what specifically they contribute to the ecosystem (which app they should produce), thus how many apps will be published or downloaded; nor does it set prices, beyond setting an acceptable range.

participants—whether they are far-sighted or not (see Jacobides et al, 2016). Whereas firms that want to encourage ecosystems are likely to push for modular structures with clear interfaces, an ecosystem may coalesce even without the focal firm's desire to open up, as happened with IBM's system 360, or Apple's early iPhone ecosystem of unauthorized apps. The understanding of "accidental" (or even illicit) ecosystems and the way they evolve is a fascinating area for future research.[25]

Ecosystem collaboration. Why do some forms of inter-organizational collaborations happen in ecosystems rather than in other forms, such as supply chains or alliances? And what kinds of collaboration and coordination behaviors are we likely to observe within ecosystems? Our framework suggests that depending on the type of complementarity, we will get a different set of behaviors—and, likely, organizing structures too. Dynamics in nascent sectors, which have received increasing attention of late (e.g., Gurses & Ozcan, 2014; Hannah, 2014), may contrast with mature settings. As we move to increasingly dynamic settings, understanding which attitudes and approaches enable the identification and then success of new ecosystems, and which might lead to their demise (West and Wood 2013), will be an intriguing area of new research.[26]

Likewise, there is benefit to a comparative analysis of *different approaches* that firms take to similar problems, with some engaging with or even creating different types of ecosystems, others choosing to rely on markets, and yet others becoming system integrators and vertically

[25] It is also worth noting that for ecosystems to operate, we need some standards and rules; and often ecosystems are most needed in emerging areas where coordination problems are rife, and these rules are sorely lacking.

[26] Study of "live experiments" such as IDEO's Co-Lab, wherein firms from different sectors come together to structure new propositions, where rules and roles are "designed" in real time can yield promising new directions.

integrated providers. Is there an inherent advantage to each of these solutions?[27] To what extent are there firm-specific skills in leveraging capabilities, or knowing how to run ecosystems, as Helfat and Raubitschek (2018) argue—and which ones matter most?

Our analysis of complementarities also offers some guidance on managing ecosystems. Under unique complementarities, we expect participants to care about ecosystem health only inasmuch as its demise would eliminate the demand, whereas supermodularity would also increase the very attractiveness of the product or service offered by ecosystem participants. This should increase collaboration propensity.[28] Furthermore, requisite investment fungibility helps shape the appropriate strategies for managing ecosystems. The greater the supermodularity and the lower the fungibility, the easier it will be to align effort for *current* participant members. This might be because the less fungible the effort required to participate in an ecosystem, the keener a participant will be to see the common enterprise succeed, as the cost of redeployment increases. However, the lower the fungibility the harder it will be to *recruit* ecosystem participants, who may fear being locked in. This implies what is likely to be a recurrent strategic conundrum to the question of ecosystem design. A better understanding of *tactics and governance mechanisms* that hub firms use to recruit, motivate, and retain participants will be helpful.

Finally, our framework suggests that we need to consider ecosystems in their *competitive context.* Fungibility of assets and relationships, for instance, is a function of how easy it is to

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[27] Consider, for instance, the challenge of electric vehicles. Different firms put together a variety of approaches, both in terms of how integrated they are, and, if they use ecosystems, what the nature of these ecosystems is (see Chen et al., 2017). Some, like Tesla, are vertically integrated and concurrently use supply networks. Others, like Nissan, use the open market. Others, like Wanxiang, use ecosystems—with distinct and incompatible ways of charging, and protected by different standards, but where participants have significant autonomy (Weiller et al, 2015).

[28] This also offers a cautionary note on our interpretation of the increasing number of ecosystem studies, as the findings of both mechanisms and outcomes will heavily depend on the nature of interdependencies. This affects finding generalizability, especially for platform-based studies (see McIntyre and Srinivasan, 2017).

redeploy them; and the attractiveness of conditions in one ecosystem is a comparative assessment of what the alternatives are. This requires a shift in empirical focus from within-ecosystem to *across*-ecosystem dynamics, as they are likely to influence each other.

Ecosystem value creation/capture. Assessing how the different types of complementarity play out can also highlight some of the underlying mechanisms of value creation and capture *in* and *across* ecosystems. Consider, for instance, the role of directionality of co-specialization. Whether fungibility is one-way or bilateral, and whether it is symmetric or stronger in one direction or another, will affect both the behavior of the actors of an ecosystem—in terms of their preference to cooperate vs. expropriate—and the recruitment of new members. The very things that make it easy to capture value *within* an ecosystem make it harder to recruit (and, less so, retain) members. This becomes even more important when ecosystems compete for members, so that members may decide to shift to another ecosystem if the conditions no longer favor them. A further interaction is that the more an ecosystem is driven by supermodular complementarities, the more hubs will initially try to focus on attracting members; yet as an ecosystem becomes dominant, recruitment takes care of itself, so that value distribution may become more lopsided.

Our framework could also help explain *competitive dynamics*. How do the rules and expected fungibility of participating in one ecosystem change as a result of actions in another? That is, how does the growth of ecosystems such as Android affect the rules, required commitments, and standards of competing ecosystems such as iOS? And how do the hub firms and participants respond?[29] Also, what role is played by regulators or social pressure groups? We

[29] We will find it hard to understand one ecosystem and its rules without direct reference to the other: to understand Hailo, we need to understand Uber, and local taxi dispatch structures too. Strategic dynamics become even more complicated when firms participate in rival ecosystems, such as Microsoft developing its MS Office Suite for Apple's Mac OS, while simultaneously trying to advocate its own software ecosystem *against* that of Apple.

can readily understand that ecosystems characterized by strong supermodular complementarities will want to become established, and then profit on the basis of the network externalities they generate—but we should also expect that regulators (and prospective ecosystem members) will want to see the exact opposite, pushing for interchangeable standards and generic complementarities that allow free entry and exit.[30]

We would expect ecosystems with supermodular complementarities to be more resilient than those resting purely on unique complementarities, but even these can be overturned through competition. This raises interesting questions that may explain, for instance, how Symbian, with 67% of the smartphone OS market (and against the predictions of most economic or strategy models), lost ground to the young upstart Android. As Pon *et al.* (2014) note, much of this is due to differences in organizational efficiency, governance, and nature of co-specialization.

Ecosystem governance and regulation. To understand such strategic dynamics, we need a clearer sense of how ecosystems are structured and governed. Behavior in an ecosystem, and ultimately its success, is affected by the rules of engagement and the nature of standards and interfaces—open vs. closed; imposed vs. emergent. Some ecosystems have clear, possibly *de jure* defined standards, especially if they have many members. Others, especially those not based on technology, might have *de facto* expectations in terms of the rules of engagement.

Relatedly, we need to compare and contrast open and closed ecosystems, with several shades of gray in between. Some ecosystems accept any participant who agrees to a minimal set of

[30] This may also have significant welfare implications, with final customers or ecosystem members benefiting in the short term, even though it might discourage ecosystem formation from hubs anxious about expropriation in the longer term. A new set of policy and regulatory questions could thus come into play—as we have seen with recent discussions on the power of Apple, Google, Facebook, and Amazon, or electric cars.

rules, whereas elsewhere membership is strictly controlled, whether by committee or by the hub—*if* there is one.[31] Rules pertaining to hierarchy or membership may change over time, as with Facebook (Claussen *et al.*, 2013). We need to understand how membership rules vary, what drives this variation (and its competitive impact), and how this relates to standards (open vs. closed; proprietary or sector-wide), modularity, and the nature of complementarities.

Our framework provides a starting point for understanding the underlying forces operating in an ecosystem, but several questions remain. What determines the level and form of control in an ecosystem? Which control mechanisms can a hub use, and when does control become so unilateral that the ecosystem becomes a supply chain? Do the mechanisms governing the ecosystem change as a function of the shifting nature of modularity, of complementarities, or other factors? Where, in particular, do we see the emergence and success of distributed governance in ecosystems, such as in the open-source movement (O'Mahony & Bechky, 2008)? Looking past the shiny success stories of strong hubs such as Apple, we should also ask what we can learn from firms that tried to become hubs but failed. We should also remember that most ecosystem members are complementors (for instance, in July 2014 there were 2.3 million individuals working as app developers), with very limited power (Pon, 2016). While research has started to consider their plight (Ceccagnoli *et al.*, 2012; Kapoor 2013; Selander *et al.*, 2013), it has mostly examined firms facing tactical decisions such as multi-homing (Bresnahan *et al.*, 2014; Mantena *et al.*, 2010). However, it remains to be understood how these firms achieve complementarities at the ecosystem level, and how participating in multiple ecosystems influences the type and intensity of such

[31] Consider different videogame consoles' ecosystems. Historically, Nintendo has set strict rules for participation, imposing exclusivity clauses and limiting the number of complements members can develop for its systems. Rival ecosystems, such as those sponsored by Sony or Microsoft, have adopted rather more *laissez-faire* policies.

complementarities, and thus the benefits for the participants of an ecosystem and its sponsor (e.g., Cennamo et al. 2018).

Back to the strategy literature. Our Appendix provides some thoughts on how ecosystem research can benefit, and contribute to, mainstream strategy research, complementing the discussion of Adner (2017). Beyond these general links, we think that the answers to the questions posed in this section can push the research agenda to revisit some of the fundamental concerns of strategy research. The ecosystem construct reaffirms the importance of considering the aggregate level of analysis in assessing firms' competitive advantage: If firms gain from others participating in an ecosystem, but cannot fully control them, what does that imply for how they attain advantage? Frameworks such as the RBV mostly concern themselves with *owned* resources. How should this perspective change when the resources exist not at the level of the firm, but at the level of the ecosystem? And, linking the RBV, dynamic capabilities, and ecosystems, what sort of resources and capabilities could be valuable for firms in this dynamic context (see Helfat and Campo-Rembado, 2015)? Helfat and Raubitschek (2018) have recently argued that innovation capabilities, environmental scanning and sensing capabilities, and, in particular, integrative capabilities are critical for ecosystem orchestration and platform leadership. The question remains, how does the value of resources and capabilities differ depending on the role firms take within the ecosystem (hub vs. participants)?

Our objective in this paper was to advance our understanding of ecosystems, and to propose elements of a positive theory of ecosystems—the role of modularity, and the impact of different types of complementarity (and the resulting fungibility) as they tie ecosystem members together in a web of interdependent yet autonomous activities. We hope that the directions offered will enrich both research on ecosystems, and research in mainstream strategy, as firms become increasingly engaged in, and respond to ecosystem growth.

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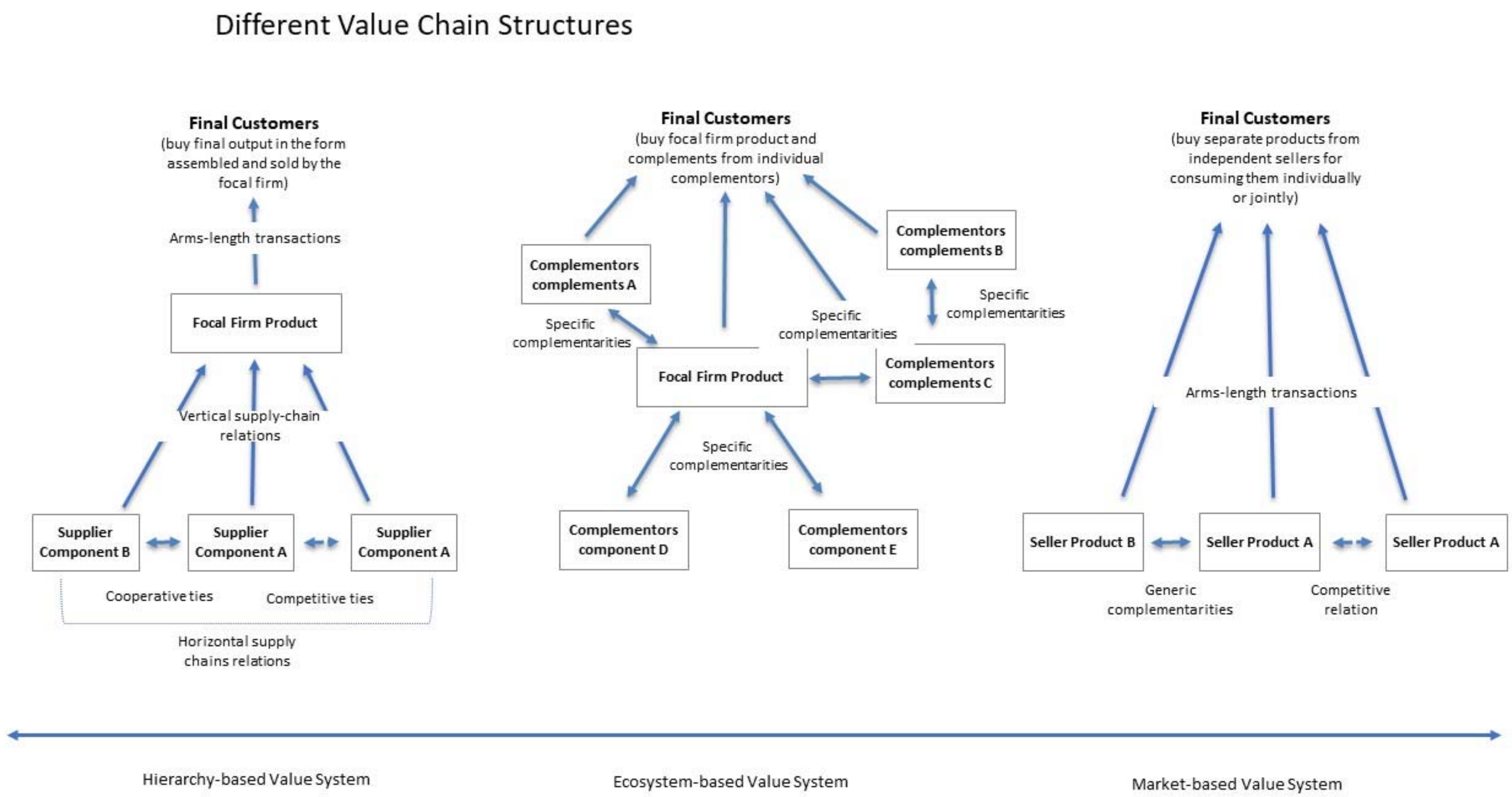

Figure 1. Different Types of Value Systems

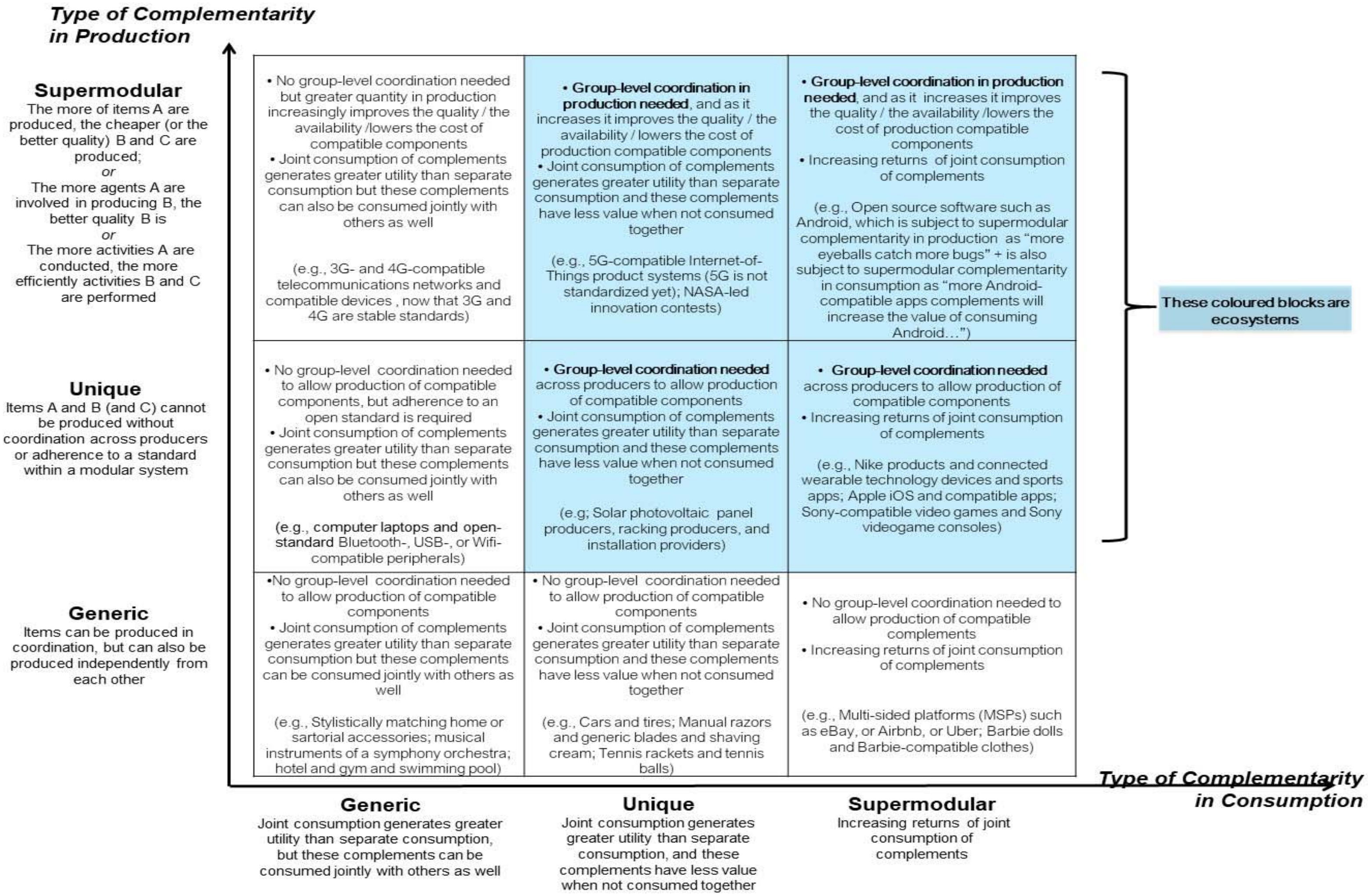

Figure 2. Types of Complementarities and Ecosystems

APPENDIX: ECOSYSTEMS' RELATION TO EXTANT RESEARCH

The real litmus test of a theory must be its ability to add value: to extend existing research, not duplicate it. In this section, we ask, "What does the ecosystem lens show us that we could not otherwise see?"

Starting with industry analysis, the focus on ecosystems appears to be a clear complement. Traditional analysis of sectors and their evolution lacks the vocabulary to consider groupings such as ecosystems or examine their dynamics. On the rare occasions that ecosystems relate to a single sector, their function is likely to affect the success of that sector, and the patterns of value distribution within it, in idiosyncratic ways that are worthy of further study. In looking at these patterns, ecosystem research would benefit if it employed specific methodologies that have been developed to study joint value creation and distribution—as opposed to merely alluding to them. So, there is gain to be had here—phenomenologically and theoretically.

Moving to recent work on Industry Architecture (Jacobides *et al.*, 2016), there are clear and strong connections. Ecosystems appear to be one of many ways that a sector or set of sectors can be structured; that is, they seem to represent a specific type of industry architecture. The nature of this architecture will affect the potential patterns of value creation and distribution both between different, potentially competing ecosystems, and between the participants in each ecosystem. There is, already, research that considers how ecosystems develop in the context of particular IAs (Tee & Gawer, 2009) and how ecosystem structure affects value distribution (Dedrick *et al.*, 2010). The concept of bottlenecks (Baldwin, 2014; Jacobides & Tae, 2015), central to IA, is clearly relevant to ecosystems too (Hannah & Eisenhardt, 2016). However, IA does not yet have a developed repertoire that examines how these specific, particular types of groupings (i.e. ecosystems) come about or are governed, or how they shape value distribution.

Research on modularity (Baldwin, 2014) could be usefully employed to help us understand ecosystems, and vice-versa. As we posited, we see modularity as a precondition for the emergence of ecosystems. But, is it the case that modular structures emerge as a result of conscious design, e.g. by hub firms? If so, what determines what gets "opened up" and what does not? When do we see modular systems emerge, and what is the role of existing ecosystems in either enhancing or interfering with modularity? What are the results of different strategic choices of hubs and of other ecosystem participants in this regard?[32]

The more established literature on alliances also stands to benefit from the construct of ecosystems. Phenomenologically, ecosystems overlap only partly with alliances (Gulati *et al*., 2012), and clearly represent a very specific subset of them. Sometimes, ecosystem relationships do not require a formal alliance, and do not bind firms, since participation in an ecosystem might merely be a function of adhering to certain specifications. However, we could consider ecosystem participation as a particular type of loose alliance, where the link between firms expresses the co-dependence brought about by their mutual co-specialization (e.g., Alexy *et al*., 2013; Kapoor & Lee, 2013). As we stressed in the text, a defining feature of ecosystems is the provision of *standardized rules* in terms of the alliances offered, which are *specific to the roles* that are acknowledge in an ecosystem. These types of standardized alliances, which need to imply some non-generic, non-fungible investment to qualify as being the base for an ecosystem could be the basis of future research.

[32] Note that the ecosystem analysis helps provide a strategic angle to the analysis of industry evolution. Consider, for instance, Langlois (1992), whose thesis is that transaction costs are a transient phenomenon, and that as contracting parties figure out a way to coordinate, hierarchy will give way to the market. Our analysis here suggests that coordination (and modularity) is designed, and while there may be *technical* abilities of shifting to a market through the use of standards, the *strategic* dynamics may not let that happen. Apple could surely create open standards and migrate away from a closed ecosystem to an open market-based structure, but this would not serve its strategic interests, and as such it will not do it. The exploration of these dynamics and of the strategic use of ecosystem as a means of organizing, and potentially dominating, through a careful design of complementarities, modularity, and of the governance of ecosystems remains a fascinating area for future research.

The nature of standardized and more bespoke alliances and (more rarely) joint ventures could become a promising area for the understanding of ecosystem governance and management. How do firms that co-sponsor ecosystems manage them? When do they use alliances to do so? Also, alliances can be used not only as tools for ecosystem participants, but at a higher level, to set the ground for *building* an ecosystem. How do these alliances differ from those that simply pertain to ecosystem participation? For instance, how did the alliance of Microsoft and Intel, by shaping Wintel and the nature of this platform ecosystem, affect both the outcome and the nature of the looser alliances between Wintel and PC manufacturers? Furthermore, the analysis of ecosystems and their associated alliances could provide fresh research questions for alliance research, since the focus would be neither on the individual alliance nor on the portfolio of alliances of a single firm (Wassmer, 2010), but rather on the alliances pertaining to an ecosystem (Hannah & Eisenhardt, 2016).[33]

Research on networks (Powerll, 2003) could also benefit ecosystem analysis, and vice versa. For all the solid work on networks, they have largely focused on the dynamics of *one industry* (e.g. Uzzi, 1997). An ecosystem (which, by definition, encompasses firms with non-generic group-level complementarities) could be mapped as a network, yet it is distinct, both because it can have a cross-sector nature, and because of the existence of a set of distinct and asymmetrical links tied at the group level by specific complementarity. There is significant value in documenting the network structure of ecosystems (Iyer *et al.*; 2006; Venkatraman & Lee, 2004), but there is greater promise in studying how network analysis metrics (such as centrality, closeness etc.) apply to such segment-spanning networks, theoretically and empirically.

[33] To be fair to ecosystem research, the alliance literature does focus almost exclusively on dyads (see Dyer & Singh, 1998); even the triad as a focus of analysis is a novelty (Davis, 2016). As such, analysis of a *structured set of alliances based on ecosystems* goes beyond the “alliance portfolio” research (see Wassmer, 2010).

To reiterate, ecosystems are defined by non-generic complementarities at the group level, which means that while there is competition to attract profits within the ecosystem, there is *alignment in how all members benefit from the success of the collective enterprise (i.e., the ecosystem)* (Adner, 2017) and thus gain advantage over another collective enterprise (i.e., another ecosystem) or a set of unrelated firms. For instance, firms participating in the Android ecosystem clearly have issues on how to divide the total spoils (between and within different parts of the value-adding process), but they also share a desire to beat the iPhone.[34] It is this particular *incentive and organizational structure,* distinct from ecosystems as we define them, that yields the mix of cooperation and competition (sometimes efficient, sometimes less so) that the literature has picked up. Thus, we have a different canonical problem from the one institutional economics focuses on—one that provides opportunities to leverage and extend existing research, much as the canonical buyer-supplier analysis led to the boom in TCE (Williamson, 1985).

Some recent research is pointing in this direction. West and Wood (2013) document how the structure of relationships and governance mechanisms between key actors in the Symbian ecosystem created conflicting incentives that constrained the ecosystem's capacity to evolve

[34] Note that the extent of such interest is a direct function of the extent of complementarity that developers have. At the margin, if an app can work seamlessly in both ecosystems, then there is little that binds these organizations together, since the success of one ecosystem is irrelevant to their prospects—they can inhabit another at zero cost. A further subtlety here is that if we take one organization that belongs to different ecosystems (such as multi-homing app developers, who work with all major ecosystems), *at the corporate level* there may be little vesting to particular ecosystems, even though at the business level, each unit tied to an ecosystem does have co-dependencies. This observation opens up another set of interesting questions. First, for firms that can participate in multiple competing ecosystems, what is the right strategy? Bresnahan *et al.* (2014), for instance, show that the two platforms in our example target different segments of consumers, thus capturing different parts of the market, which not only explains why they can coexist, but also why app developers find it beneficial to participate in both, without having a vested interest in one ecosystem withering. Second, some complementors may act strategically, and decide to multi-home to prevent a single platform ecosystem winning (eg., Cennamo & Santaló, 2013). In the videogame industry, developers such as Electronic Arts have used this multi-homing strategy to increase their value capture ability vis-à-vis any single platform. As such, over and above the strategies of "the focal firm," we can develop rich typologies and prescriptions for strategies of firms that consider their participation in multiple ecosystems.

and create a thriving market for applications such as those later created by Apple and then Google. With a clearer understanding of the underlying dynamics, we can progress further.[35]

Ansari et al. (2015) document how TiVo, a start-up firm that pioneered the digital video recorder in the U.S. television industry, elicited greater acceptance and support for its disruptive technology (even from incumbents) by influencing positioning and relationships among members of the evolving TV industry ecosystem. Kapoor and Furr (2015) show how, in the solar photovoltaic industry, complementarities at both the firm and ecosystem level can explain the diversifying technology choices of firms participating in an ecosystem, while Hannah and Eisenhardt (2016) look at how different firms within one ecosystem followed diverse strategies in the attempt to strengthen their positions and become the bottleneck.[36]

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[35] There is an increase in studies that consider the ways in which organizations shape their ecosystems—and the implications of these choices. Gatignon and Capron (2017) consider Natura, a Brazilian eco-friendly cosmetics firm, and show how it built an ecosystem, linking with underprivileged women across Brazil and tribes in the Amazon and other biomes to ensure the distribution and supply of its products. They point out that Natura chose not to become the sole hub, but rather to create a broader ecosystem involving entire communities as well as public, private, and non-profit partners collaborating together, given that the benefits from this multilateral approach outweighed its expected benefit from being the sole hub.

[36] Note that, per the narrow definition of ecosystems we advocate, while bottlenecks are integral parts of ecosystems, bottlenecks can also emerge *outside* ecosystems. In a related set of sectors, where there is a unique but generic set of complementarities (e.g., the requirement of rare earths for the production of mobile telephony devices) the relatively more scarce component *even in a sector with no ecosystem-like arrangements* may lead to a bottleneck in the spirit of Jacobides and Tae (2015), Baldwin (2014), or Ethiraj and Posen (2013). If there are some non-generic complementarities, however, then we will have both ecosystem dynamics *and* bottlenecks—and the design of the ecosystem may *lead* to bottlenecks.