Evolution of digital platform-based ecosystem: A theoretical framework

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Abstract. Digital platform ecosystems, which function as complex socio-technical systems that facilitate interactions between various actors through developing an IT architecture and governance regime, needs to develop and adopt to ensure long-term sustainability. Previous researches provide largely descriptive accounts of digital platform-based ecosystem evolution (DPE) outcome rather than the dynamic process. Against the background, this paper puts forward an integrated conceptualization of DPE as a complex dynamic process. Through a systematic literature review of previous studies, we induct a theoretical framework that explains how digital platform ecosystem evolve over time in repose to unpredicTable challenges. Our findings present the endogenous dynamic and exogenous dynamic influences how they co-evolution, then combine the Lenses for Theory to analyse the evolutionary dynamics. Overall, we contribute to conceptualize the digital platform ecosystem and enrich the theoretical connotation for the co-evolution of the business ecosystem.

1. Introduction

Researchers in information systems propose networks of independent actors that they name as an "ecosystem" [1–3]. Just as biological ecosystems consist of a variety of interdependent species, business ecosystems analogously depict interdependent networks of organizations. Digital platform ecosystems (DPE), which function as complex socio-technical systems that facilitate interactions between various actors through developing digital architecture and governance [2]. Some of today's most successful companies such as Airbnb, Google are at the centre of digital platform ecosystems with various actors that interact enabled by the underlying platform architecture and governance.

It is not surprising that there is a growing number of studies on digital platform ecosystem evolution. Some studies focus on evolutionary outcomes, such as growth, variety of complementors or market dominance [2, 3]; others offer descriptive stage models of platform evolution; there are also studies that investigate how changes in platform context lead to certain evolutionary outcomes. However, extant research is mostly descriptive with findings distributed across individual studies, it does not fully account for the events that trigger digital platform ecosystem evolution [3, 4]. Research on the co-evolution of business ecosystems only focuses on static descriptions of results, which mainly explains "what happened", such as the category of complementarities and market dominance. In recent years, although scholars have recognized that the co-evolution process is the core of the business ecosystem, the business ecosystem in the context of the platform economy is what and how to evolve still lacks substantial exploration. Arguably, systems that are not designed to evolve are likely to irrecoverably fall behind those that are, as are the organizations that depend on them [15].

As such, we lack theory that explains how digital platform ecosystem evolve over time in repose to unpredicTable challenges. Moreover, how digital platform ecosystems follow different evolutionary trajectories that leads to certain outcomes. Our argument proceeds as follows. First, we summarize existing perspectives on digital platform ecosystem. We then present a framework for understanding platform-based ecosystems to guide our empirical analysis and theory development. Finally, we combine these findings with extant literature to explains how triggering events and

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drive digital platform ecosystem evolution. Our contribution in this study is twofold. First, the conceptual connotation, structural framework and key elements of the platform ecosystem are clarified. Second, the causal relationships affecting the co-evolution of the platform ecosystem are discussed.

2. Literature review

The evolution of digital platform ecosystem remains elusive topic in the early literature [1, 3]. Although researchers recognize that the architecture of digital platform is evolvable from the engineering perspective [5] and the number of ecosystem actors grows over time from the economic perspective, there is lack of systematic approach towards studying digital platform ecosystem and evolution process.

2.1. Technology Platforms

The use of the term 'platform' has recently proliferated in management research across a variety of domains [2]. Value, design, and management of platforms has been a topic of increasing interest to both researchers and practitioners [6-8]. In the context of the network economy, the platform has become the backbone of many technology industries, not only promote the development of new products and services, but also shape business model and influences strategic development [9]. Relevant research is based on the understanding and definition of different aspects of the platform [3], which mainly includes three fields: industrial economics, technical management and strategic management.

Digital platforms are oftentimes regarded as technological systems, as a technical artefact, "as the extensible code-based system that provides core functionality shaped by the modules that interoperate with it, and the interfaces through which they interoperate". Increasingly they are also seen as management and economic concepts, creating value by providing products and services that enable two or more different types of customers to find each other and exchange value. Importantly, the overall value of platform requires players, such as developers who build tools, to operationalize the exchange. Conceptualization of platforms has been developed separately by two streams of academic literature – industrial economics and engineering design.

Armstrong (2006) and Rochet and Tirole (2006) suggested that technology platforms are multi-sided markets since they bring together various types of participants, or sides, such as buyers and sellers [8]. Consequently, studies have examined pricing and commitment incentives to market participation. Other studies have used various lenses to understand platform competition emergence, strategies, strategic differences, and the role of complementary markets.

The platform is usually conceptualized as an entity or virtual "market intermediary" that facilitates value creation by connecting different products and services. The value of the platform depends on the size of participants and other users [2, 3]. For example, the value of Facebook, an online social networking platform, is directly proportional to the number of registered users. In addition, the platform provides complementary products and services that directly or indirectly enhance user value [8].

2.2. Business Ecosystem

Ecosystems as a modern concept of inter-organisational networks are often discussed in current information systems research. Business ecosystems were initially described by Moore and by Iansiti [10, 13]. They were established in the context of economic and organization sciences but occur also in the information systems literature. An ecosystem consists of interdependent firms that form symbiotic relationships to create and deliver products and services. The conceptualization of markets as ecosystems is a result of theoretical extensions of work in networks, alliances, and innovation. The term "business ecosystem" was first introduced in the mid-1990s [10] and subsequently has become pervasive in strategic management. This theory renews traditional

competitive advantage and resource-based view, provides professional view on co-evolution and co-creation [11, 12].

Business ecosystems are defined as networks of organizations that are formed around a central innovation, technology or company. The main focus is to establish economic relationships between the different participants around a focal technology. The existing research focuses on actors, the relationships between them and economic effects. To date, there exist three primary streams of literature related to business ecosystem research. The first stream emphasizes the definition of the concept and domain of the business ecosystem [10]. The second stream focuses on investigating the role played by the various ecosystem firms and their strategies for surviving and thriving within a business ecosystem [13]. The third stream studies the governance framework and sustainability of the business ecosystem [14].

2.3. Platform-Based Ecosystem Evolution

Platform ecosystems emerge around a focal platform. The platform provides a combination of hardware, software and infrastructure as well as organizational and social rules that connect actors around the platform [6]. The evolution of platforms often tends to follow a so-called winner-take-all dynamic where one platform gains dominance and a gatekeeper role. The aim of platform ecosystem is the co-achievement of all actors involved. In our research, we define platform ecosystems as organizations that (a) offer a scalable and modular technological architecture, (b) create value by managing and governing independent ecosystem partners, and (c) the existence of network effects between these ecosystem partners and the platform's customers. Based on these characteristics, platforms have an inherent incentive to rapidly grow the number of third parties, including partners and customers. As a complex social-technical ecosystem, the platform-based ecosystem also has the unexpectedly evolutionary trajectory which remains elusive topic in early literature [14]. There is a lack of systematic approach towards evolutionary processes of ecosystem. Recently, scholars have noticed the dynamic evolutionary process, which mainly focuses on co-evolution perspective [1].

Building upon early research on resolvability of digital platforms [5], Tiwana et al. (2010) argue that digital platform ecosystems develop through co-evolution of architecture and governance in response to environmental dynamics [15]. Early research deconstructed the platform architecture (decomposition, modules and design rules).The "gear" relationship with governance (decision, control, and ownership). As digital platforms promote external participants through software resources, common interfaces, and interfaces, some scholars begin to analyse the performance patterns of third-party complements and study the co-evolution of platform core (generating) and peripheral (diversity). On the one hand, scholars believe that resource allocation through boundary resources can increase the productivity of ecosystems. On the other hand, external application development will destroy the platform owner's position to a certain extent, so strict governance rules are needed.

3. Empirical Approach

In this paper we employ synthesis literature review. Our review was conducted using the ISI Web of Knowledge database to collate published journal articles, which contain the search term "ecosystem" in the title, Abstract, or keywords, and which appear in the "platform" or "platform ecosystem evolution" research domains. The collated articles (n=170) were in turn systematically scoured through to define the members of business ecosystems and their roles, to reveal the factors important for the evolution of these ecosystems, and to shed light on the dynamics of ecosystem change.

In our analysis we identified several articles which emerge as seminal works that have made substantial contribution to the business ecosystem research field. The works of Gawer (2002) and Iansiti and Levien (2004) provide definition of business ecosystems [13]. Tiwana et al (2010) elaborates on the evolution of business ecosystems, Adner and Kapoor (2010) shed light on the

dynamics of change in ecosystems. These articles form the backbone of our elaborated findings that follow [16].

4. Research Findings: Theoretical framework

4.1. Conceptualization of Digital Platform-Based Ecosystem

This study suggests that the digital platform ecosystem can be conceptualized as a network or symbiosis system interconnected by entities, as shown in the figure. The platform ecosystem has broad and narrow meanings. Narrow platform ecosystem includes technology platform and application services; the broad platform ecosystem includes end users, a competing platform ecosystem, and a competitive environment.

Digital platform function as the core of ecosystem, the boundary resource is connected to modular complement. under the governance rule, the system actors (supply and demand users, and stakeholders, platform owner or provider) can interact to value co-creation [2, 17].It can be seen from the above literature that the platform ecosystem is based on the network structure, and multiple participants realize the value creation through the platform architecture to form a dynamic symbiotic ecosystem [3, 16].

As a symbiotic-dependent ecosystem, a platform-based ecosystem can be conceptualized as a network of entities or nodes, as shown in Figure 1. In the context of platform economy, core platforms and ecological species (such as suppliers, demanders, complements, and regulators) achieve value creation through the circulation of information, capital, and materials.

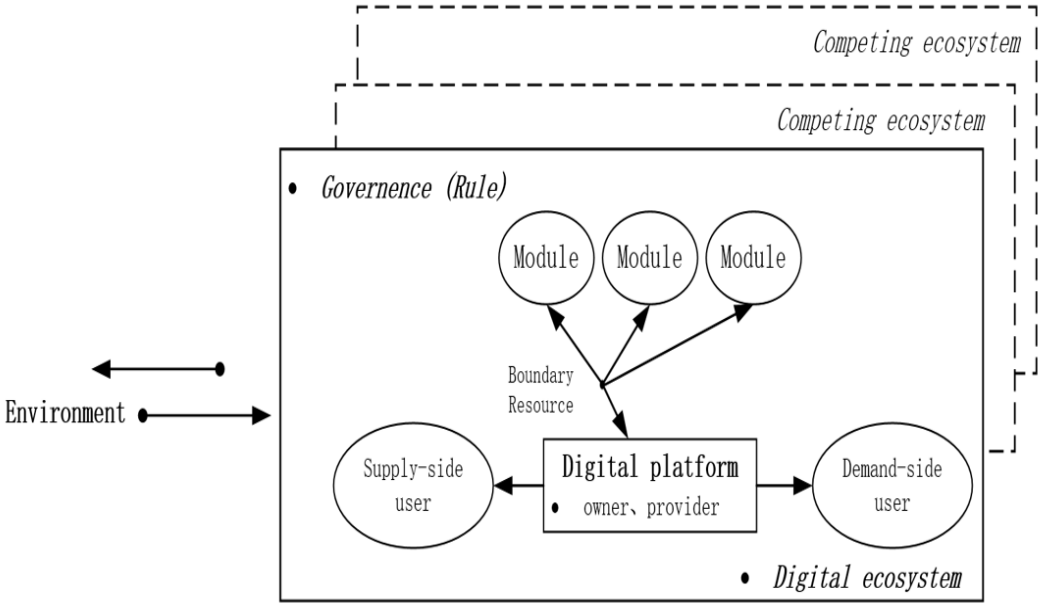

Figure 1: Firgue1 Elements of digital Platform-based Ecosystems

Identifying key elements is critical to understanding the overall definition of ecosystems [18]. After reviewing carefully the existing conceptualizations in the platform literature, I propose an Encompassing definition of digital platform ecosystems and outline their main characteristics. As a complex business ecosystem, the Digital Platform Ecosystem (DPE) is based on the digital platform architecture and promotes the value of interaction between ecological species (enterprises, suppliers, partners, customers) through governance rules. Literature and related practices show that the key elements of DPE are: ecological species, platform governance, and architecture (IT).

As an anchor point of the ecosystem, the digital platform provides rules and boundary resources for accessing the ecosystem. Digital platform ecosystems consist of a number of actors, each assuming different roles. Platform users can be demand-side actors that consume services, which are offered by supply-side actors through the platform. The architecture of a digital platform ecosystem encompasses the platform core, the periphery around it and the boundary resources,

which connect the core and the periphery [1, 15]. The fundamental feature of a platform architecture, in our view, is that certain components remain fixed over the life of platform. The governance regime consists of various rules that regulate access, participation, and value appropriation in a digital platform ecosystem [1]. To identify their sub-constructs, I review and synthetize the relevant platform and ecosystem literature. The study further illustrates the elements and components of the digital platform ecosystem (as shown Table 1).

Table 1 Definitions of Core Concepts Underlying digital platform ecosystems

Concept	Definition	Representative reference
Digital platform	Complex IT functional components that are extended based on the platform's original architecture that provide layered and module logic.	Baldwin and Woodard 2009; Hanseth and Lyytinen,2010; Tiwana, 2014
Digital ecosystem	The collection of digital platform and the module specific to it.	Cusumano and Gawer 2002; Ghazawneh and Henfridsson, 2012
Actor	The heterogeneous actors(platform owner, provider, supply-side users and demand-side users) involved in the social construction of digital platform ecosystem	Eisenmann et al., 2009; Evans,2012; Gawer and Cusumano,2014; Hagiu, 2016; Ondrus et al., 2015
Architecture	The structuring of a digital platform core functionality, periphery module and boundary resource	Baldwin and Woodward, 2009; Eaton et al., 2015; Gawer and Cusumano, 2014; Ghazawneh and Henfridsson, 2013; Tiwana, 2014
Governance	The rules that regulated access, control mechanism and value appropriation in DPE	Boudreau and Hagiu, 2009;Evans and Schmalensee, 2016;Parker et al.,2017; Tiwana, 2014

4.2. A Framework for Evolutionary Process of Digital Platform-Based Ecosystem

We develop the overarching idea that the evolutionary dynamics of digital platform ecosystems and their modules is influenced by the co-evolution of the endogenous to the ecosystem (e.g., actor, platform architecture and governance) and the environmental dynamics exogenous to the ecosystem. Figure 2 presents a research framework that provides a road map for the subsequent discussion.

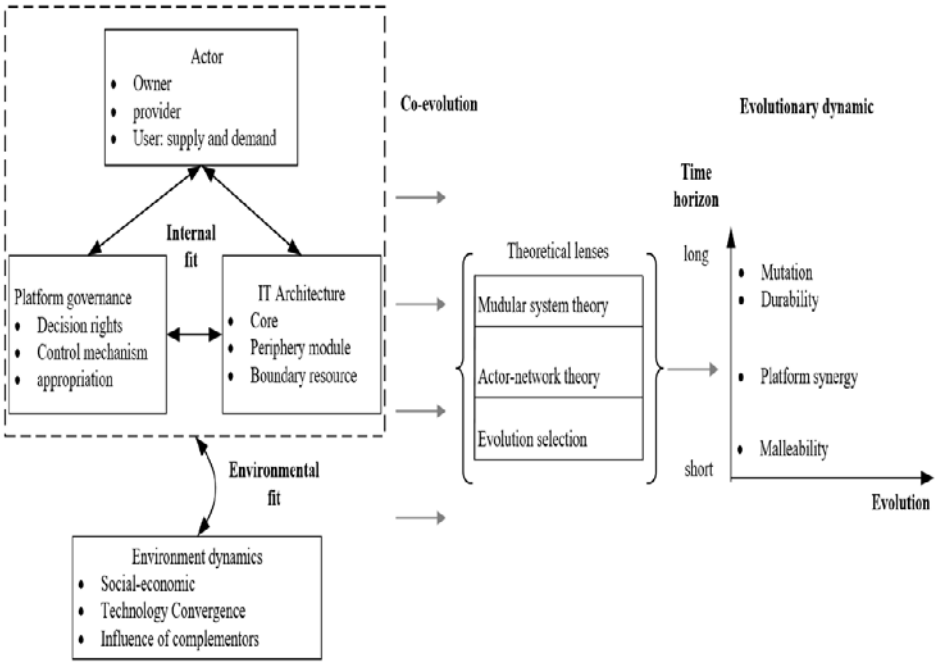

Figure 2: framework of digital platform ecosystem evolution

4.2.1. Endogenous Factors of Evolution

Ecosystems evolve subsequent to endogenous and exogenous forces a fundamental force internal to the ecosystem is the 'co-evolutionary processes' among actors of the ecosystem, as interdependent organizations evolve reciprocally with one another [10, 19].

First, actors. Based on relevant literature and management practices, this study believes that ecological members mainly include: platform users, platform owners, and platform operators. Platform users include platform provider users and demand-side users, which implement value interaction through the platform [2]; platform owners control platform design, IP and other participation rules, platform operators participate in platform production (such as technology provision) and distribution cooperation, and the two can be mutually integrated and coexist.

Second, ‘Platform architecture’ subsequently emerges as another endogenous factor that governs the evolution of ecosystems. The ecosystem's architectural design is typically made by keystone organizations, who, in their design, must meet the challenge of forecasting future changes in the ecosystem because the platform architecture is often irreversible [15]. The digital platform architecture is the core of ecosystem evolution. Due to technical uncertainty, the platform architecture must adapt to the natural selection of internal and external environments. This study believes that the digital architecture mainly includes: core components, peripheral modules (additional subsystems), and boundary resources (such as API, SDK).

A further endogenous factor that influences the evolution of the ecosystem is ‘platform governance’. The central theme in platform governance is the amount of decision making and control (or coordination) that platform owners should relinquish to other members of the same ecosystem. Governance is the way in which the platform owner influences the ecosystem and is also the Catalyst of evolution development [15, 16]. This study believes that governance rules mainly include: decision-making power and access ownership of the platform system; ecosystem participation and division of labour rules; platform pricing and value distribution policy. These rule elements also evolved in the evolution of ecosystems.

4.2.2. Exogenous Factors of Evolution

Three environmental dynamics in particular deserve theoretical attention. First, the technological trajectories (e.g. rapidity, scope, and Unpredictability with which complementary technologies) are emerging can affect their evolution. Technological convergence can offer opportunities for a platform to expand into the domain of adjacent but unrelated platforms and allow unrelated platforms to offer the focal platform’s functionality as part of a multiproduct bundle [2].

Second, Convergence is laden with envelopment opportunities, particularly because adjacent platforms often have overlapping user and developer bases. Technological convergence can offer opportunities for a platform to expand into the domain of adjacent but unrelated platforms and simultaneously allow unrelated platforms to offer the focal platform’s functionality as part of a multiproduct bundle.

A third environmental dynamic is the power or influence exerted by complementors that directly or indirectly provide services to one or more platforms but are not part of the module developer community. Complementors who influence the platform ecosystem include government departments, intermediary associations, and industry organizations. The government's regulatory power and policy orientation have also become important environmental forces that affect development.

4.2.3. Lenses for Theory: Evolution Selection Theory

The premise of the theory of evolutionary selection is that complex systems that evolve at a faster rate and with greater diversity are more likely to evolve to achieve better fit with their environment than those that do not possess these traits [15]. Three theoretical perspectives can

provide useful lenses for developing causal explanations linking actors, platform architecture, governance, and environmental dynamics at the module or ecosystem level: (a) Punctuated Equilibrium Theory, (b) modular systems theory, (c) Actor-network theory.

First, Punctuated Equilibrium Theory has been developed so far, and the theoretical framework has been continuously improved, but they all follow the same paradigm: the long-term equilibrium phase (steady state) and the short-term mutation phase (mutual state) alternate. This Theory states that socio-technical systems evolve through relatively long periods of stability, followed by shorter periods of rapid and pervasive change, which destabilize the existing deep structure. To drive the change process and to produce various change outcomes [20], Punctuated Equilibrium Theory relies on evolutionary mechanisms as causal structures, which account for the ongoing reinforcement and transformation in a system's deep structure.

Second, Modularity refers to the property of any complex system that intentionally minimizes interdependence between its subsystems Complex systems such as platform ecosystems are composed of interacting subsystems that are always to some degree interdependent [21]. The premise of modular systems theory is that a complex system composed of smaller subsystems that interact exclusively using predefined, sTable interfaces is more amenable to change than those that are monolithic. Then, Actor-network theory by which multiple human actors translate and inscribe their interests into a technology, creating an evolving network of human and nonhuman actors.

Finally, network models assume that networks of human and technical elements drive digital infrastructure evolution. This stream of research is typically grounded in some of the early writings of actor-network theorists such as Callón (1986) and Latour (1987). In Actor-network theory, there is no opposition between the subject and the object. Each node is a subject, an actionable actor, and each other is in a position of equal rights. The inter subjectivity is an inter-subjective relationship and relationship that mutual recognition, mutual recognition, interdependence and mutual influence. Non-human actors obtain the status, qualifications and rights of the subject through qualified "agents" so that they can work together to create a network of coordinated actions.

4.2.4. Evolutionary Dynamics in Ecosystems

Tiwana (2015) believes that evolutionary indicators can measure and feedback the evolution of platform's ecological behaviour, rather than the performance indicators of the results [15]. Therefore, this study divides the metrics into business or strategic, and covers short, medium and long-term. Among them, short-term indicators are mainly structural flexibility and user stickiness; medium-term indicators are mainly platform synergy and plasticity; long-term indicators include system mutation and persistence.

The short-term evolutionary features of the platform ecosystem can be portrayed by resilience and expansion. Resilience refers to the ability to perform satisfactory functions when the subsystem encounters force majeure, that is, the immunity of the subsystem, such as reliability, stability, responsibility; Extensibility refers to the function and financial scale of the subsystem, reflecting the sub-system. The number of end users and software developers that can be supported by the system.

The medium-term evolution of the platform ecosystem can be characterized by plasticity. Stickiness refers to the subsystem's main user group. Plasticity refers to the transfer of new functions in subsystem development. Long-term evolutionary features of the platform ecosystem can be used for boundaries and mutations and persistence. Once the control platform successfully creates a network effect, it is difficult to be replaced, mainly because the network effect can be used in place. The system is also difficult to break the user's dependence on the in-place platform ecosystem.

5. Conclusions

In this article we undertook a literature review to synthesize the work that has been conducted by scholars studying digital platform-based ecosystems. Through a systematic literature review of previous studies, we induct a theoretical framework that explains how digital platform ecosystem

evolve over time in repose to unpredicTable challenges. Our findings present the endogenous dynamic and exogenous dynamic influences how they co-evolution, then combine the Lenses for Theory to analyse the evolutionary dynamics. Overall, we contribute to conceptualize the digital platform ecosystem and enrich the theoretical connotation for the co-evolution of the business ecosystem. This article is not without its limitations. First, there is a lack of multi-case studies to empirically test the theoretical framework. Second, the correctness and scientific nature of the evolutionary framework of the platform ecosystem needs to be further tested.

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